THE REPUBLICAN RIVER BASIN AND THREE IRRIGATION DISTRICTS:
A SOCIO-HYDROLOGY PROFILE

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Submitted to the graduate degree program in Geography and Atmospheric Science and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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Date Approved: December 13, 2017

ABSTRACT

Water and people's co-evolution has been marked upon the landscape by visible stream diversions to massive hydroelectric dams, while more reclusive impacts like water table levels are beneath the earth's surface. Both actions have reconfigured the hydrological ecosystem, creating spatial patterns and social relationships centered on water. Accessing water emerges as a dominant catalyst for economic development on the U.S. Great Plains. I examine the co-evolution of people and water on the U.S. Great Plains with a socio-hydrological profile that focuses on three irrigation districts in the Republican River basin.

The socio-hydrological profile consists of several elements. One, historical and legal aspects of water detail how they impacted its use and management. Two, a policy implementation assessment dissects the challenges presented by the governing 1943 Republican River Compact and supporting 2002 Final Settlement Stipulation agreement. Three, streamflow scenarios for simulated and observational data illustrate the river's changing character through time and space. Four, interviews with irrigators, managers, and other important stakeholders illuminate how they are keenly interested in water's value and management.

As the first socio-hydrological profile of the irrigation districts and the basin, my findings present a holistic representation of the co-evolution of people and water. The profile identifies four periods — droughts and floods, science and technology, litigation, and future adaptation and interpretation — that have and will shape the basin's social and water relationship. I suggest that current socio-hydrological research add thematic categories to the values and norms component of the socio-hydrological organizational nexus.

Key Words

Republican River, socio-hydrology, trans-border conflict, irrigation districts, water management, environmental policy

ACKNOWLEDGEMENTS

Although my dissertation carries my name and all the errors are mine, many people have contributed to my journey by offering their encouragement and assistance.

Barney Warf, who is not a water researcher, was willing to accept me as an advisee. He helped me clarify my ideas and develop strategies to tackle a project that had multiple moving parts. Burke Griggs shares a common interest in the Republican River basin and its water challenges. As a recovering historian and lawyer, his attention to detail and patience explaining water law has been invaluable. Dorothy Daley introduced me to the practical importance of language for public policy analysis and implementation, as well as being brief. I did not meet that challenge in writing the dissertation. Alex Diener assisted me as I worked on my interviews and shared his essential check-list for graduate school success. Dave Mechem's more quantitative approach to models and streamflow helped me focus on the essential results, eliminating unnecessary details. Johannes Feddema was also instrumental in the development of my streamflow scenarios. A special thank you to Dorothy and Burke for being interested in my topic and finding time to serve on a geography committee. Along the way my advisors forced me to stretch my intellect and to be a more thoughtful scholar.

Important thank you's to the Frenchman-Cambridge and Bostwick Irrigation District managers and boards of directors, the Nebraska Department of Natural Resources, the Kansas Division of Water Resources, and the Colorado Republican River Water Conservation District for their gracious cooperation answering questions and providing data. Other agencies and individuals contributed as well. I received funding support from the University of Kansas's Geography Department's Kollmorgan Scholarship, the Graduate School's Summer Research Fellowship, the Institute for Policy and Social Research, and the Osage Chapter of the Association of Women Geoscientists.

My classmates and Lindley 117 office mates provided entertainment, advice, and support throughout my journey. Jennifer Glaubius, Meghan Kelly, and Emily Fekete became and remain friends through our shared trials and tribulations. Jen, Travis White, and Anna Wieser read many, many pages of my initial drafts in our online writing group. They made insightful and important suggestions that improved my final draft. KU Geography alumni John Bauer made my maps and acted as a sounding board, and Jeremy Dillon made suggestions for my many graphs. Liz Thomas and Travis provided graphic and cartographic help.

Finally, I want to thank my family. Every summer my parents Jim and Mary Patterson took Patti, Jim Dan, Susan and me camping out West. Those trips are the genesis for my love of geography. When I decided I needed to pursue a doctoral degree, they all voted 'yes.' My children Connor, Phoebe, and Ciara and my husband Bruce voted 'yes,' too, even though it meant he had to be at home with two teenage girls. While I sometimes bemoaned my voluntary journey, they offered their mostly loving patience and encouragement. Thank you most sincerely and with love.

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LIST OF ACRONYMS AND DEFINITIONS

AFY = acre feet/year

Compact = Republican River Compact
Corps = U.S. Army Corp of Engineers

FCID = Frenchman-Cambridge Irrigation District
FSS = Final Settlement Stipulation

KBID = Kansas Bostwick Irrigation District

NBID = Nebraska Bostwick Irrigation District
NDNR = Nebraska Department of Natural Resources

Reclamation = U.S. Bureau of Reclamation
RC = Red Cloud, Nebraska
RRCA = Republican River Compact Administration
- RRCA/B = RRCA Benkelman stream gauge site
- RRCA/H = RRCA Hardy stream gauge site

RRWCD = Republican River Water Conservation District

STF = St. Francis, Kansas
USGS = United States Geological Survey
- USGS/B = USGS Benkelman stream gauge site
- USGS/H = USGS Hardy stream gauge site

WB = Water Budget (Balance)
- WB/STF = WB St. Francis COOP weather station

Chapter 1
The Republican River Basin and Its Socio-Hydrology

The U.S. Great Plains is simultaneously beautiful and harsh. A slow, undulating landscape unfurls beneath a distant horizon that stretches in every direction. Those vast horizons can signal hope and fear in the form of well needed rains that water crops and fill streams or tornadoes, droughts, and blizzards that call for shelter and endurance. For those who farm and ranch in the Plains, climate is both friend and foe, requiring adaptation and adjustment.

Perhaps more than any other factor, water is the critical component to survival and success in a place where it can be scarce and unreliable. Precipitation ranges from 10”-15” (25-38 cm) in the west to upwards of 25” (63.5 cm) or more at the region’s eastern side (Bleed 1993; Bicek 2002). As a result, many streams are intermittent and overall stream density is low as compared to the eastern half of the U.S. Some Plains’ streams are fed by dense mountain snow pack and others are prairie or flashy streams that depend on seasonal precipitation events.

For much of the region’s history, competition for water was generally limited. As westward migrations to the Great Plains began in the mid-1800s, water demands by people increased. Surface water in streams is the most readily available on the Plains. Stream diversions and canals became a common practice for farmers; later municipalities and industries also would put demands upon that water. If groundwater was easily accessed, it was used, too. Depending on conditions and people’s access to water, winners and losers were inevitable. During periods of prolonged drought, competition and conflict occurred between surface water users. Solving these disputes eventually led to territorial and state water practices, such as ‘first in time, first in right,’ a prior appropriation system that developed in the California gold fields and diffused eastward. Individuals or groups who first claimed a stream’s water had first rights of use during shortages. Those and other practices eventually became codified as state statutes, where water belongs to the state’s citizens and beneficial use is allowed.

As part of the U.S. federal system, states have sovereign control over their internal affairs. Water is a transitory, non-human, and non-political entity that pays no heed to socially imposed borders. However, once water is commodified and takes on a market-culture value, exploitation and conflict are inevitable (Sherow 1990). Addressing water conflicts that cross socially imposed political borders is legally challenging. Further aggravating the situation are hydrological borders that counter the political. Because streams typically cross state lines, transboundary conflicts between states over a stream’s water eventually came to the fore, and so did a solution; interstate river compacts.

The first interstate river compact was the 1922 Colorado River Compact between seven U.S. states. The Upper Basin (Wyoming, Colorado, Utah, New Mexico) cannot deplete streamflow to the Lower Basin (Arizona, Nevada, California); to do so is to risk legal action. Six more interstate river compacts followed by 1950 (Table 1.1). The first three — the Colorado, LaPlata, and South Platte — owe their genesis to the vision of Delph Carpenter, a Colorado lawyer who saw a need to minimize water lawsuits between states and offered interstate compacts as a means to do so (Tyler 2003; Rettig 2017a).

Table 1.1. U.S. Interstate River Compacts, 1922-1950

YEAR	COMPACT AND STATES
1922	Colorado River (Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada, California) La Plata River (New Mexico, Colorado)
1923	South Platte River (Wyoming, Nebraska)
1939	Rio Grande (Colorado, New Mexico, Texas)
1943	Republican River (Colorado, Kansas, Nebraska) Belle Fourche River (Wyoming, South Dakota)
1948	Upper Colorado (Wyoming, Colorado, Utah, New Mexico, Arizona)
1949	Arkansas River (Colorado, Kansas)
1950	Yellowstone River (Montana, Wyoming, North Dakota)

While compacts offer a legal means to ensure that each party receives its annual allocation, the actual water quantity can fluctuate significantly. Both annual precipitation variability and technological advances impact surface streamflow and groundwater quantities. Since the advent of those initial compacts, developments in hydrology and engineering have confirmed the hydrological connectivity between surface water and groundwater. The 1950s introduction of submersible groundwater pumps offered a drought-proof alternative to inconsistent surface water irrigation during the growing season. However, groundwater pumping can adversely impact surface water flows, diminishing its volume.

As a result of its climatic and hydrological conditions, water on the Great Plains is not reliable or accessible without technology. Human interference in the hydrological relationship between surface and groundwater along with other factors including climate change and farm practices has altered the region's waterscapes since the 1940s. A devastating flood in the midst of the 1935s Depression killed over 100 people in the Republican River basin and wrecked havoc on its infrastructure and economy (Manley 1993). That event, combined with the 1930s Dust Bowl, and the need for reliable agricultural water motivated the residents of Colorado, Kansas, and Nebraska to create the 1943 Republican River Compact (hereafter Compact). In conjunction with the U.S. Bureau of Reclamation (hereafter Reclamation), large-scale infrastructure projects were developed that provided flood control, created irrigation districts, and supplied each state with an equitable water allocation from the Republican River.

The Republican River begins in eastern Colorado, flows through a corner of northwest Kansas, and then along the southern portion of Nebraska before again moving into north-central Kansas (Figures 1.1, 1.2, 1.3). Its "virgin waters undepleted by the activity of man" (Republican River Compact Article II) are shared among the three states. Initially, surface flows were able to meet the needs of the basin's federal irrigation projects, the Reclamation's Bostwick and Frenchman Creek Divisions, as long as there was not a drought. With the advent of intensive groundwater pumping, surface flows began to diminish even during normal precipitation periods. Eventually the surface flow losses forced Kansas in 1998 to sue its upstream Compact partners, Colorado and Nebraska. Surface flow losses also encouraged local Nebraska surface water users to challenge groundwater users and state agencies. Despite legal rulings, the larger conflict of a changed socio-hydrological relationship continues amid the basin's water market-culture.

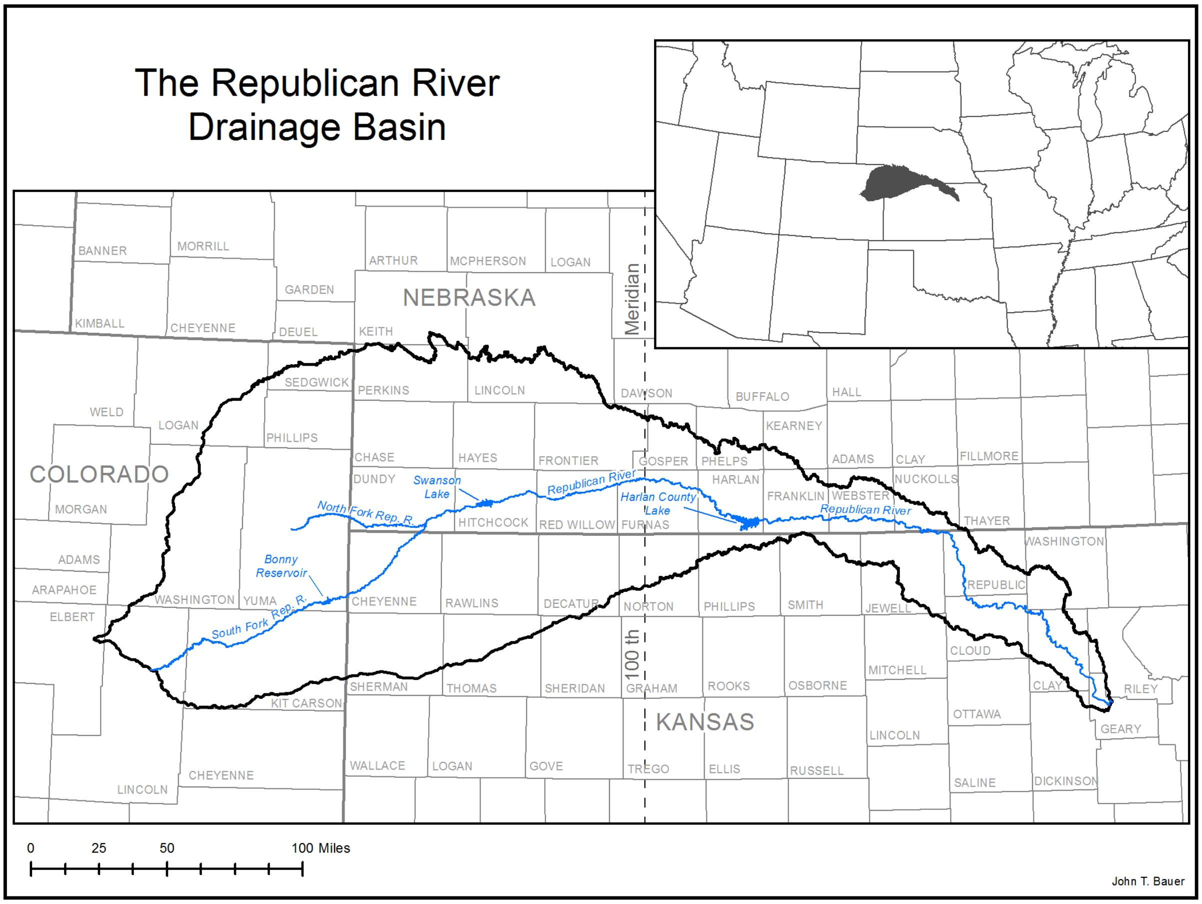


Figure 1.1. The Republican River Basin (Bauer 2017).

Figure 1.2. The Republican River near Cambridge, Nebraska (Knapp 2015).


Figure 1.3. The Republican River at Concordia, Kansas (Author).

Dissertation Question

My dissertation research is focused on three Republican River basin irrigation districts — the Frenchman-Cambridge Irrigation District, the Nebraska Bostwick Irrigation District, and the Kansas Bostwick Irrigation District. It examines how the socio-hydrology of the Great Plains is reflected in the Compact, its associated irrigation districts, and the waters of the basin.

How do the basin irrigation districts and their members value water, and why? How do they interact with other water users and agencies, both within their community and outside their state? What do they foresee for water's future in the basin? These questions and others are worth exploring and are best done so through the field of socio-hydrology. Socio-hydrology examines the relationship on the landscape between people and water from a hydrological perspective. Geographers often describe this relationship as hydro-social, but the essence of both is the inescapable role of water in people's lives and society.

I construct a socio-hydrology profile that tells the districts' story through time and space. It includes a description of the basin and its development, water law and policy, a policy analysis of the Compact and the Final Settlement Stipulation (FSS), an analysis and comparison of the river's streamflow from three sources, and interviews with irrigation district stakeholders. By synthesizing these factors into a profile, I offer a more holistic picture of the basin that includes both its agricultural community and its water, its socio-hydrology. Further, I suggest policy implementation assessment additions and historical socio-hydrological thematic categories to better define and conceptualize how future research may be approached.

Dissertation Organization

The remaining dissertation chapters are first placed within the context of earlier scholarly work, and are followed by chapters that present the socio-hydrology profile elements individually; they are integrated in the conclusion.

Chapter 2 places my research within the larger scholarly discussions of the history of nature, contemporary explorations of nature and water, and socio-hydrology. A trajectory of dynamic as well as static responses to nature and water can be drawn illuminating how water has been perceived and acted upon by human agency through time. Since it is virtually impossible to separate people from water, knowing how scholars have studied and reported on society's relationship with water anchors my research to a larger discussion of nature.

Chapter 3 describes the study area's physical and social attributes along with infrastructure details of the irrigation districts. These details give an overview of the basin that ties its physical characteristics to human agency's historical interaction with the basin's hydrological cycle. Further, it sets the tone for later water conflicts between users, states, and agencies.

Water history, law, and policy are the focus of Chapter 4. Detailed explanations are provided that define different types of water and water laws. It gives a historical overview of each states' water law development from territorial to contemporary policies, and explains how interstate river compacts came to be a means for addressing interstate and trans-basin water conflicts, including the Republican River. It is important to understand how water law evolved and how the states responded to their waterscapes through legislation, so that the current conflict between the states and surface and groundwater users are placed in a historical and legal perspective.

Because the basin is under the governance of the Compact and the subsequent FSS, I conduct a policy implementation assessment using Mazmanian and Sabatier's (1981) policy process theory in Chapter 5. My assessment focuses exclusively on how the language of the legal documents molds the responses to and success or failures of the Compact and the Final Settlement. Most particularly, I examine what is and is not stated, and how those inclusions and omissions color actions and responses by the states and the irrigation districts.

Surface water streamflows are the lynch pin of the irrigation districts and the Compact; declining flows are causes of intense concern for the irrigation districts. In Chapter 6 I present three different streamflow scenarios from three different sources to explore how water management decision-making over time and space has impacted the river's hydrological cycle and surface flows for the irrigation districts and their users. One source offers an alternative simulated streamflow scenario, while the other two present observational streamflow scenarios. Water management decisions are clearly represented in the observational data, attesting to the human impact on streamflow and human agency in the basin. Solutions to the declining flows are controversial and contingent on legal, political, economic and hydrological realities.

Key basin stakeholders share their perspectives of the basin's water and legal landscapes through semi-structured interviews in Chapter 7. Few studies to date have examined how surface water users feel about water, the legal boxes in which they function, and their relationships with other water users and agencies in the basin. Knowing what their viewpoints are advances context about past conflicts and current challenges are an opportunity to better understand the social ramifications and interactions of people.

The conclusion, Chapter 8, presents a historical socio-hydrology profile composite based on the individual components that offers a more cohesive setting for the basin. I expand the socio-hydrological organizational framework by suggesting the addition of thematic categories for socio-hydrology to pursue that include social factors, values, and norms in hydrological modeling. Thematic categories better define and conceptualize how future research may be approached. Theoretical concerns are also addressed.

CHAPTER 2
NATURE, PEOPLE, AND WATER

Civilizations reflect a group's social and cultural values, and water is central to their long-term viability. Consider the spatial distribution of major civilizations like the Egyptians, Romans, or Mayans where agricultural irrigation canals diverted water to fields for food production, aqueducts transported water to far away cities, and seaside ports meant ships could ply the oceans for trade. Societies and cultures can flourish and grow with water; without it they wither and disappear. Water has been and continues to be the lifeblood of survival at multiple scales from the personal to the economic because people need it every day. It can be in abundant quantities, severely limited, of high or low quality, and provides sustenance. It is used on farms and in factories to produce goods and services, and is delivered by rain, snow, or a kitchen faucet. People and water have co-evolved across time and space.

My research explores the relationship between people and water on the U.S. Great Plains and how people have spatially leveraged surface water to promote irrigated agriculture. I use three irrigation districts in the Republican River basin to examine the human-water relationship that includes water management, governance, and conflict. I apply a socio-hydrological lens to assess the interaction.

Over time many scholars have questioned and sought answers to explain how they and nature are connected, their spaces and relationships, and how one has shaped the other. Scholarly work on early environmental history, social constructions of water and nature, and water research hybrids that explore the social-nature interactions including socio-hydrology are presented in the chapter.

EARLY APPROACHES TO NATURE

Clarence Glackens's *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century* (1967) is the authoritative text on the relationship between nature and people up to the 1800s. Early ancient writers and thinkers wrestled with explaining and understanding humanity's place in and relationship to nature in an attempt to create a holistic view of nature, laying the groundwork for the recognition and acceptance of human agency as well as ecological theory (Glacken 1967). Today the scientific community agrees that people are a geographic agent imposing environmental changes through open pit mining, deforestation, and increased CO_2 levels, to name but a few examples.

Scientists, philosophers, and geographers of the Renaissance and Age of Discovery showed an increasing recognition of global environmental change. Intellectual resources and interpretations gained depth and breadth with secular environmental theories that physical systems have their own functionality, and nature its own history separate from people. Immanuel Kant in particular felt that people should be considered in the study of physical geography and environmental change, a precursor to modern ecosystem services and socio-ecosystem services relationships (Glacken 1967). Count Buffon, the 18th century French natural historian and first Western scientist to focus on human impacts, subscribed to the idea that people's agency and power was equivalent to the agency of geography and geology. People impose social systems upon and into natural systems from simple dwellings to complex drainage projects that reconfigure ecological and hydrological relationships.

How people have altered the Earth and how the environment influences social development remain persistent questions and were marked upon the mid-1800s American landscape with George Perkins Marsh's *Man and Nature* (1864). His discourse on human agency and its relationship with nature explored how to both exploit resources in the present and preserve them for the future. Geographers Alexander von Humboldt, Karl Ritter, and Arnold Henry Guyot advocated studying the physical world's role and influence on social life and the progress of people (Marsh 1864; Lowenthal 2000). That echoed earlier ideas that relationships found in law, human society, and moral causes could be traced to relationships with the physical world (Glacken 1967). Later critical geography border scholars note how societies create borders based on current needs, desires, and perceptions (Buchanan and Moore 2003) as well as the inclusion of ethics (Brunn et al. 2005). These border constructions are reminiscent of earlier ideas of the role of nature in social and political development.

Scientists Charles Lyell (the classic *Principles of Geology,* 1835) and Mary Somerville (*Physical Geography*, 1848, the definitive text into the early 1900s), and anarchist and French geographer Elisee Reclus (1873) readily acknowledged human agency and environmental impacts (Goudie 2013). Mary Somerville astutely said "Man dexterously avails himself of the powers of nature to subdue nature" (in Goudie 2013, 4), and Reclus wrote that "the action of man may embellish the earth, but it may also disfigure it; according to the manner and social conditions of any nation, contributes either to the degradation or glorification of nature" (in Goudie 2013, 5). These observations ring true today in the Republican River basin, where substantial water control infrastructure projects have attempted to wrestle water into subservience to irrigation districts and their water users at a cost to the streams and hydrological system.

In the 20th century, two philosophies appear, the inspirational and the economic (Lowenthal 2000). Those who followed the inspirational path believed that nature and wilderness had an intrinsic value greater than resource use. Those focused on economic returns continued with modification via human agency like "the fantasy that tree planting would water the plains, even convert the Great American Desert into a well-wooded land" (Lowenthal 2000, 7). Contemporary responses call for integrating social values and technical solutions, but social values have always played a role in how the environment has been studied, perceived, and used.

As an environmental historian, Lowenthal offers contemporary approaches to nature including its social construction and nature as an everyday affair, where non-academics and ordinary people are engaged with decision-making. Scholars study nature's social constructions and how people interact with and contribute to water resource decision-making at multiple scales with theoretical and practical applications. On the other hand, basin actors are engaged in water management consulting and decision-making on a day-to-day 'real life' basis.

THE 20TH CENTURY

The environment's influence on man and man as a geographic agent continue to be relevant themes in Post Modern geography and theoretical thought. Gold (1984), Swyngedouw (1997), Fitzsimmons (1989), Proctor (1998), Castree (2001, 2005), Demeritt (2002), Inkpen and Wilson (2013), and others have explored the questions, "what does it mean to be human?" and "what is nature?"

Gold (1984) reminds us that during the Renaissance and Age of Discovery, emerging capitalism had a role in burgeoning scientific inquiry because it was a means to explain the how and why of nature. Science allowed people to examine the outside world from the atom to the celestial to gain an understanding and appreciation of systems, parts, and their interactions singly and in concert. Space exists regardless of a human presence, but how it is defined and used by people determines its value to individuals and society at large. For people living in the Arkansas River basin of Colorado and Kansas, water came to have a market-culture value to irrigators and corporations that have challenged how social and natural space are defined (Sherow 1990).

Fitzsimmons (1989) argues that everything is urban, that all environments are socially constructed, and therefore there is no such thing as a purely rural area and there is no nature apart from human beings. A pristine, untouched wilderness is unrealistic according to Cronon (1996), especially as people have migrated, settled, and penetrated ever more remote areas. Nature has been and continues to be perceived and manipulated to serve specific social goals that include economics, science, philosophy, and agriculture. Nature and all its elements is not apolitical because its use and designation are identified with a group's particular worldview (Fall 2011).

Nature and The Social Construction Of Water

Studies of the world and its phenomena endeavor to control and define spaces, whether social or natural. Furthermore, both spaces are inherently politicized and imbued with power (Glacken 1967; Gold 1984; Braun and Castree 1998; Castree 2001, 2005; Castree and Braun 2001; Braun 2002; Demeritt 2002; Fall 2005; Bakker and Bridge 2006). Constructs define parameters for objects and experiences that lead to a common group understanding. They vary among groups, over time, and through space, allowing societies to define themselves as well as others (Buchanan and Moore 2003; Cloke and Johnston 2005; Montanari 2015). These social constructions have tended to create binaries that identify and mark spaces, such as earthly-heavenly, global-local, frontier-homeland, or human-nature.

In geography, the primary binary was human-physical, although the history of geography shows that this was not always the case and that it came about only in the mid-20th century (Castree 2005). In the last few decades Haraway (1991), Latour (2007, 2011), Whatmore (2002), and others (see Braun 2006; Cloke and Johnston 2005) have criticized these binary constructions by proposing that they oversimplify reality. They suggest a better representation would be a relative relationship between different phenomena in the guise of cyborgs, Actor Network Theory, and hybridity that connect binaries thereby demonstrating the porosity of these artificial and socially constructed borders. Additional discussion revolves around how society has inserted itself into nature (Swyngedouw 1997, 1999; Whatmore 2002; Giglioli and

Swyngedouw 2008). As a binary, human-nature does not adequately describe people and the inhabited world. The Republican River basin irrigation districts' slogan is "Water is Life" (Figure 2.1) and spotlights water's central role in their social-water-agriculture nexus.

Figure 2.1. Bostwick Irrigation District, Red Cloud, Nebraska (Author).

Furthermore, binaries or even dichotomies are no longer adequate representations because they largely ignore the symbiotic, interactive, and interconnected socio-nature system (Swyngedouw 1997). Instead, the former spatial and social distinctions have become integrated in socio-ecological systems that are supported by ecosystem services, blurring even further any borders between people and nature. Socio-hydrology can be one means of minimizing the socio-nature binaries, and I do concede that the name itself is suggestive of a binary.

The remainder of the chapter addresses philosophies about the human-water cycle, the hydrosocial and socio-hydrology. First, I provide a broad overview of water and its social context as a resource and potential conflicts that can arise over its abundance, scarcity, and location. Second, I summarize the language and research paradigms associated with the two positions based on work by Wesselink et al. (2017). Third, I offer Erik Swyngedouw's work (1997, 1999) as an example of hydrosocial research. Fourth, I highlight ecosystem services and socio-ecological systems as a transition to socio-hydrology. Finally, I discuss socio-hydrology, noting early and recent support for its work, as well as its ambitious goal to include dynamic, qualitative data into hydrological models that are used in water management decisions.

Water and Water Hybrids

Water easily bridges the social-nature divide. As part of the hydrological cycle, water undergoes movement and transformations of state while being used for personal and economic needs. Greater or lesser precipitation means more or less water for streams and its downstream users, ecosystems, agriculture, and municipalities. Water excesses and shortages present challenges, but it is over-use and over-allocation in conjunction with natural deficits and water scarcity that claim the most attention. In the Republican River basin, it is both.

The abundance-scarcity cycle is a planning challenge for individual users and water management decision-makers, where often complex and competing policies can pit public and private actors and ecosystems against each other. Because it can occupy multiple political spaces and have numerous types of users, usage practices, and historical policies, water is a contested resource space (Popelka 2004; Horne 2010; Smedley 2011). "Fair and equitable allocation" is an oxymoron for many who deal with water disputes that cross boundaries, as each actor tends to privilege themself, while nature and its systems often lose (Brunn et al. 2005; Bear and Eden 2008; Craig 2010; Ioris 2013; Ward 2013). Water within a single political unit may pose fewer allocation conflicts than water that crosses jurisdictional boundaries from international to inter-state, but power relations inevitably color the boundaries those allocations represent (Dellapenna 2007; Schlager and Heikkila 2009; Fall 2011; Garrick et al. 2013; Meehan 2013; Ward 2013). Space itself has networks and hierarchies of scale, yet space is continually molded, distorted, and reconfigured by people.

Through both natural cycles and social activity, water development and its extraction vary with regard to resource conditions, eliciting questions such as: Has it been a wet, normal or dry year? Has the recharge rate kept pace with extraction rates? Has technological change reduced or increased water use? or Has agricultural, industrial, and municipal demand changed? Subsequently, water is in a state of near constant flux due to human activities, weather and climate conditions, and local geologic and hydrologic conditions. Researchers take various approaches to answering these questions. Those in human geography term theirs hydrosocial and those in hydrology term theirs socio-hydrology. I explain the differences below.

LANGUAGE CHOICE IMPLICATIONS: HYDROSOCIAL, HYDRO-SOCIAL AND SOCIO-HYDROLOGY

Language is important philosophically when studying the human-water cycle. *Socio-hydrology* is a relatively new term and field that emphasizes the spatial organization of people around water. *Hydro-social* or *hydrosocial* has a long geographic history and different meanings with and without the hyphen. With the hyphen people and water are seen as more independent actors, while the hyphen-less version is indicative of a hybridized relationship. Wesselink et al. (2017) have written an excellent paper, "Socio-hydrology and hydrosocial analysis: toward dialogues across disciplines," which disassembles each of the ideas, their legacy, and history drawing upon recent and long-standing publications. They offer a lucid analysis of the research paradigms associated with each idea, clearly delineating their advantages and shortfalls. They do so to answer three pragmatic questions for human-water systems: What is learned with different approaches? What rationales for action are suggested? and is complementarity between them possible?

Hydrosocial systems can be traced to critical human geography through human-water and social-nature power relations (Wesselink et al. 2017). Ontologically the hydrosocial world is built on two conditions: decision-making powers and the impacts they have on inequality, and the relationship between people and water as an *internal* one, making water and social power (or society) hybrids. As a result, water and social power are not separate entities, telegraphed by the lack of a hyphen. Wesselink et al. (2017) note that researchers have used Latour's Actor Network Theory because the human and non-human actors are equivalents having equal significance. Researchers also identify specific (social) objectives they want to champion including democratic parity, unlike socio-hydrologists who claim a more objective and solution oriented stance. While the authors find hydrosocial case study narratives rich in detail and texture, they lack an appreciable equivalent of time spent on physical systems and how they work, as opposed to socio-hydrology. They note the possibility of collaboration between geographers and hydrologists via Castree (2016) and others' calls for critical physical geography and social contracts that can address ongoing global changes. Those two groups will have to overcome different paradigms, prestige inequalities, and power dynamics within their respective fields to successfully collaborate on human-water issues. Wesselink at al. (2017) suggest narratives or stories as a means to moderate the differences between geographers and hydrologists, since narratives help impose order on random events through the use of a plot's logical structuring. Narrative use is based in part on Phillips' (2012) identification of eight basic narrative styles that are employed to communicate earth science results including cause-and-effect and emergence. Because both groups ontologically agree that the world is complex, narratives could serve as a bridge between their differences, for socio-hydrology acting as an input, and for hydrosocial acting as an output. For an overview of the two research paradigms see Table 2.1.

A HYDROSOCIAL EXAMPLE

Erik Swyngedouw, renowned Marxist and hydrosocial geographer, researches political ecology with a special emphasis on water resources, focused on melding social and physical systems or processes into a "politically progressive socio-natural theory" (University of Manchester n.d.). Such an approach works to intertwine society and nature as one, whose systems and networks are incomplete without the other. He has written extensively about society's internalization of water beginning with his work on water and urbanization in Ecuador (Swyngedouw 1997). He interrogates the social power necessary to domesticate water and push water's ecological frontiers farther when urban development overruns it. That is, water is brought directly within the social urban sphere with little to no regard for its spatial production source, local ecological and social impact, or social and hydrological sustainability. For example, a pipeline that moves water from an undeveloped rural drainage basin to another within an urban development moves water outside one ecological niche into a socio-ecological niche. Swyngedouw observes that any transformation between urbanization and water is reliant on economic capital and social power relations among different agents of the hydro-social cycle, that in turn if not overcome, at the least join together the political, socio-economic, and ecological to minimize the social-nature binary.

Table 2.1. Hydrosocial and Socio-Hydrology Research Comparison

	HYDROSOCIAL RESEARCH	SOCIO-HYDROLOGY
PARADIGMS	Constructivist, critical theory	Positivist, Post-Positivist
ONTOLOGY	Holistic; parts constitute each other and cannot be separated	Objectivist; holistic; parts can be separated, interaction gives emergent properties
EPISTEMOLOGY	Subjective	Objective
MAIN METHODOLOGY	Historical materialist analysis	Quantitative Modeling
STARTING POINT	Society (and technology)	Natural System
KEYWORD	Power	Interaction
AXIOLOGY	Critical or interpretivist; researchers cannot be and should not be neutral	(Post) Positivist; researchers are and should be neutral

(Wesselink et al. 2017)

His work on the Spanish waterscape (Swyngedouw 1999) furthers the thesis of water politics and the hybridity of water overcoming the social-nature divide. Is water a hybrid? Simply placing it at the crossroads of society and nature does not automatically confer hybridity. Being able to function within two different spheres or realms is contingent not on the sphere in which the actor finds itself, but on the actor's ability to meet the socially constructed expectations designated by people. For him, questions remain about control, action, and power in the production of a social-nature and the repercussions that are created. Swyngedouw stresses the urgency of scholarly work in tackling how social power is differentiated into economic, cultural, and political realms, and perhaps importantly whether or not they are democratic. Those realms are integral to water management because they help to create unique socio-environmental organization (Swyngedouw 2009). These approaches contrast with that of socio-hydrology where the physical is foregrounded over the social.

Ecosystem Services and Socio-Ecological Systems

Collins and Evans (2002) note that scientific practices are socially constructed, those constructions need to be acknowledged, and science's privileged role in decision-making practices reassessed. Few argue that science is value-free or completely objective, since the simple act of choosing variables has some degree of implicit bias. In short, data are never free from the theory that leads to their selection and interpretation. Transparently incorporating society and its values into science's research and management decision-making is difficult, and can risk social alienation and potentially greater environmental crises depending on the chosen value inclusions.

Gordon "Jeff" Fassett, current Nebraska DNR Director echoed those ideas to some extent in his confirmation hearing before the Nebraska Natural Resources Committee. He testified to committing to better science-based decision-making at the Nebraska DNR by helping the public understand water science through better communication efforts (talking and listening) that validates their concerns and priorities about how to manage water (N-NRC 2016). However, values can differ among groups and over time, and state statutes require adherence to specific behaviors. Simply listening to constituents and educating the public about water science is no guarantee of acceptance or value adherence.

Water is an ecosystem service (ESS) particularly from an economic perspective. Ecosystem services may be the ultimate in the commodification of nature. In large part, they are the benefits people derive from ecosystems (Millennium Ecosystem Assessment 2005), usually at a cost to an ecosystem. ESS is part of the larger socio-ecological system (SES). Machlis et al. (1997) first described SES as a human ecosystem for organizing and managing 'natural' ecosystems. SES is dynamic and adaptive with spatial and functional social, biological, or geographically defined boundaries. It integrates bio-geo-physical and social elements with regular and sustained activity across time and space at multiple scales, for example, corn, climate, soil type, and commodity pricing. These social and ecological systems are themselves social constructions. Hydrologists have turned to socio-hydrology as means to examine people and water (Sivapalan et al. 2012). Wesselink et al. (2017) suggest that socio-hydrology could be construed as a new iteration of SES that places water at the system's forefront as opposed to the social.

From a geographic and spatial perspective, socio-hydrology is one means to address and explain the porous human-nature border for water. Hydrologists and modelers have begun to explore how dynamic social values can be incorporated into hydrological models, so that they adequately represent this relationship. They recognize that largely static hydrological models do not fully convey the symbiotic nature of people and water, particularly in light of increased water demands, climatic changes, and a human influenced water cycle (Elshafei et al. 2015; DiBaldassarre et al. 2015; Wheater and Gober 2015; Ceola et al. 2014; Ceola et al. 2016; Pande and Sivapalan 2017). Water and people cannot be untangled. Socio-hydrology provides an opportunity to delve into how social behaviors impact water, and how the hydrological system drives social perceptions of water, its use, and its management.

SOCIO-HYDROLOGY

Socio-hydrology is an emerging field of hydrological study that considers the social and spatial organization of people around water in the landscape; further it envisions a co-evolution of people and water that uses observations, understanding, and prediction to blend two complex and dynamic systems into a single, elaborate coupled model (Sivapalan et al. 2012; Sivapalan et al. 2014; Troy et al. 2015). Early research included theoretical discussions, critiques, modeling trade-offs, water management, community preferences, globalization, climate, and other factors that contribute to water demands and water management via hydrological modeling (Lane et al. 2013; Lane 2014; Blair and Buytaert 2016; Mount et al. 2016; Pandi and Sivapalan 2017). While there is an acknowledged need to incorporate water management decision-making and social preferences (Troy et al. 2015; Chen et al.

2016; and Cosgrove and Loucks 2015), actually including those scenarios within hydrological computational models is difficult, so proxy data such as population growth or land use have sufficed to date. Troy et al. (2015) support the basic hypothesis of socio-hydrology as a system of two-way feedbacks, where actions in one realm, hydrology, directly impacts the other realm, society, and vice versa-thereby creating a co-evolution system. Sivapalan et al. (2014) support interdisciplinary collaboration with a use-inspired science approach to address water problems that utilizes two-way coupling or feedbacks.

> According to Sivapalan et al. (2014, 226), socio-hydrology has three goals:
>
> (1) analyze multiscale, space-time patterns and dynamics of socio-hydrologic processes and interpret them in terms of underlying structural features of biophysical and human systems and their interactions;
> (2) explain and interpret socio-hydrologic responses in terms of outcomes relevant to human well-being, and discern possible future scenarios of their evolution; and
> (3) understand the meaning and value of water as a culturally, politically, and economically embodied resource necessary to human life, and to do so in a manner that explicitly accounts for biophysical and human interactions.

They further envision the goals as a three-part organizational framework of structure and dynamics, outcomes in terms of well-being, and values and norms (Figure 2.2). Sivapalan et al. (2012) argue for the inclusion of social components like economics, technology, and norms to explain water sustainability problems that remain unsolved without social inputs. They advocate three approaches for future research: historical socio-hydrology (time), comparative socio-hydrology (space), and process socio-hydrology. Historical approaches examine past practices both near and far that provide insights about governance and technologies. Comparative approaches look at similarities and differences between places emphasizing climate-landscape-human controls in order to understand process and temporal dynamics. Process approaches would emphasize causal relationships as a compliment to historical and comparative research. It is an inquiry focused on the human-water co-evolution and emergent patterns. My research falls within goal three and historical socio-hydrology for the Republican River basin irrigation districts, since I am focused on understanding the human relationships that shape the water perception and management landscape.

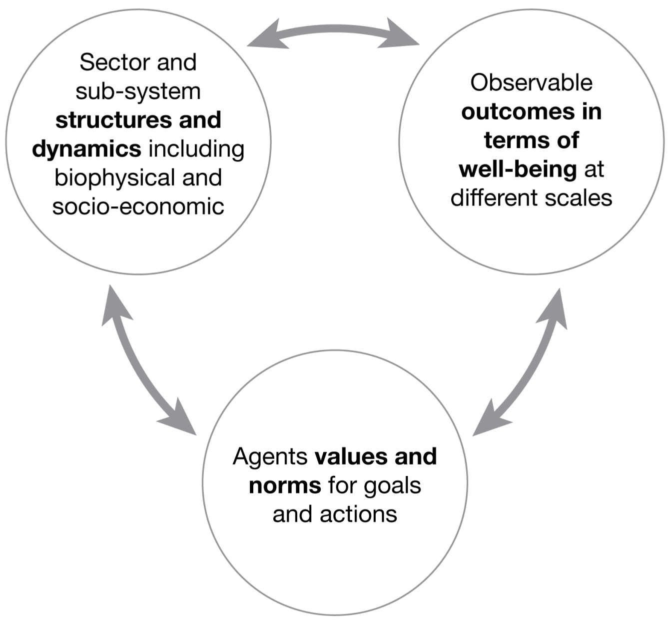


Figure 2.2. Socio-Hydrology Organization Framework. Based on Sivapalan et al. (2014, 226) (Author).

One challenge to any socio-hydrology model is predicting system response times — in other words, how long does it take for the hydrological or the social system to respond to a change, and what will that response be. Response times have temporal and spatial components. Some are long periods of time with expansive areas such as increasing daily minimum temperatures, while other responses can occur quickly at a smaller scale like localized flooding. System responses can be simultaneously both known and unknown such as a slope's angle of repose (DiBaldassare, Brandimarte, and Beven 2016). If, as the socio-hydrology hypothesis suggests, there are two-way feedbacks, calculating an algorithm and designing a model to represent those relationships is no easy task because each system interacts and responds to the other (Troy et al. 2015). Furthermore, social decisions and responses can happen quickly and may be hard to predict.

Attention and Research

Hydrosociology, coined by world-renowned hydrologist Malin Falkenmark, is part of the human-water co-evolution dynamic. It clarified the need for a more diverse approach to water planning and management in both the social and water realm (Falkenmark 1979). She and co-authors developed and defined issues that have continued and expanded as research avenues such as water scarcity, blue (liquid) water and green (moisture in soil) water, the Falkenmark index (or water stress index), and policy implications for land-water-ecosystem nexuses (Falkenmark 1977, 1979; Falkenmark, Lundqvist, and Widstrand 1989; Falkenmark and Rockstrom 2004, 2006; Rockstrom et al. 2009). As a member of the U.N. Millennium Project for 2002-2006 she was noted for work that tied climate, water use, technology, and water management to the number of people a society can support (U.N. Millennium Project 2006).

Bellie Sivakumar (2011) highlights water conflict and cooperation with the intent of drawing attention to resolving current and future water crises in light of increasing water demands and inadequate management practices. Developing new methods and techniques for planning and management that compliment effective practices are critical particularly in light of water consumption and transboundary river basins, for example. Better water education and laws, political and economic factors, and strong communication tools that use accessible language for stakeholders, particularly those outside the scientific community, are necessary to resolve water conflict and improve water cooperation.

Those proposing interdisciplinary inclusion for addressing and managing solutions to water demands in diverse regions, climates, and societies include Malin Falkenmark and partners for water scarcity and ecohydrology among many others (Falkenmark 1977, 1979; Falkenmark, Lundqvist, and Widstrand 1989; Falkenmark and Rockstrom 2004, 2006; Rockstrom et al. 2009), Elinor Ostrom and colleagues, who use a polycentric governance approach (Dietz et al. 2003; Cox et al. 2010; Ostrom 2010a, 2010b), Kate Brauman and collaborators, who use an ecosystem services approach (Brauman et al. 2007; Foley et al. 2011; Brauman, Siebert, and Foley 2013), and resource management and law perspectives from Tanya Heikkila and Edella Schlager and peers (Matthews 2005; Dellapenna 2007; Harse 2009; Heikkila et al. 2011; Katz and Moore 2011; Rose 2011; Schlager and Heikkila 2011; Schlager et al. 2012; Ward 2013; Agrawal 2014).

The International Association of Hydrological Sciences (IAHS) called for a scientific decade, “Panta Rhei — everything flows” for 2013-2022. It emphasizes developing hydrological models that can account for human impacts in drainage basins, encourages hydrologists to examine more closely social system impacts on hydrology like socio-economics, and sets scientific targets such as estimation and prediction, with the aid of key scientific questions that include where are our knowledge gaps for hydrologic change, among a number of other goals (Montanari et al. 2013; Mount et al. 2016).

The American Geophysical Union's Water Resources Research group followed up the IAHS call and presented five articles, "Debates — perspectives on socio-hydrology" (Montanari 2015) that began addressing Panta Rhei goals. The centerpiece is an article by DiBaldassarre et al. (2015) that examines social choice relative to flood hazards and specific methods to predict future behaviors — a socio-hydrological approach. Responses to their proposed methods come from Loucks (2015), Gober and Wheater (2015), Sivapalan (2015), and Troy et al. (2015) who all address the need for social inclusion, while at the same time noting the difficulty associated with including human behavior, social choice, and values. My research emphasizes identifying the social variables that influence water management decisions in the Republican River basin, and more broadly for other regional applications.

DiBaldassarre et al. (2016) follow the previous work and discuss the role that lack of knowledge, or uncertainty, plays in human-water dynamics with three categories: known unknowns, unknown unknowns, and wrong assumptions. They posit that an interdisciplinary approach is needed to clarify human-water interactions with known unknowns (we know we don't know) and wrong assumptions, using numerous studies for floods, agriculture, drought, and irrigation that have employed interdisciplinary tactics. They point out "that the study of human-water systems should first aim to understand and simulate how the human-water systems actually work, including spontaneous social dynamics, informalities, values, and norms" (2016, 1753). Technically they propose a methodology through the use of differential equations that couple social and hydrological data for hydrology, demography, technology, and society. They utilize green and technical societies to describe social responses, and engage model development that can reflect local customs and responses. Green societies are generally responsive to changing conditions, exhibiting the adaptation effect, while technical societies use technological fixes like dams, as their responses demonstrating the levee (Ciullo et al. 2017). In the Republican River basin, residents practice both strategies. After the deadly 1935 flood, they employed a technical fix with the construction of dams and reservoirs to provide flood protection; associated irrigation districts supplied reliable water (Manley 1993). As surface water allocations for irrigation have decreased in concert with declining basin streamflows, districts and users have incorporated green fixes buy adapting no till field practices and center pivot irrigation to cut costs yet maintain productivity.

My research is placed in a socio-hydrology rather than hydrosocial perspective. Hydrosocial research includes a researcher's bias towards existing power dynamics within a system. Socio-hydrology focuses on interactions and systems with a more neutral or objective positioning that I believe better frames my research. My dissertation's purpose is to explore elements of the social environment and how they connect to the hydrological environment without pursuing a specific political or power agenda, although they are endemic to the basin's social structure. I do that by exploring how Kansas, Colorado, and Nebraska use the Republican River Compact's legal guidelines and groundwater model without inclusion of social indicators, such as economics that directly impact the irrigation districts. My socially oriented research adds a contextual narrative and description of the basin, suggestive of the types of social data and methodology that will be needed for realistic socio-hydrological representations. It also supports the call for collaborative problem solving and research as espoused by Wesselink et al. (2017) along with others like Castree (2016).

CHAPTER 3
THE REPUBLICAN RIVER BASIN AND IRRIGATION DISTRICTS

Chapter 3 describes the physical and socio-economic setting of the basin, the irrigation districts and their governance, and how Reclamation and the U.S. Army Corps of Engineers contribute to the basin's socio-hydrology. These characteristics and actors are windows into the basin's environment and early development and are necessary for understanding the basin's evolving socio-hydrology.

SOCIO-ECONOMIC FACTORS

The basin's population of over 92,000 people (circa 2016) is expected to decline and age, and only 20% age 25 or older have a Bachelor's degree or more (RRCA n.d.c.; U.S. Census Bureau, n.d.; Table 1.1). Because the basin and its counties are rural, agriculture is prevalent. The economic impact of those rural counties, however, is important to their region and their state. In 2016, Nebraska ranked 5th ($7,254 million), Kansas 11th ($4,608 million), and Colorado 27th ($2,294 million) for agriculture, forestry, fishing, and hunting's contribution to their state's GDP according to the Bureau of Economic Analysis (U.S. Department of Commerce n.d.; Figure 3.1). Without water economic viability and agricultural production would largely cease to exist. There are 2.7 million irrigated acres in the basin; 1.6 million in Nebraska, 550,000 in Colorado, and 435,000 in Kansas (Brookfield and Wilson 2015). Any hydrologic change such as decreased surface water flows ripples into legal, economic, and social spheres affecting the basin's socio-hydrology relationships.

Table 3.1. Republican River Basin Select Counties Comparison

	Yuma, County, CO	Perkins, County, NE	Red Willow, County, NE	Republic County, KS	U.S. Average
% Population Change (Est. April 1, 2010 to July 1, 2016)	0.6	-2.4	-3.0	-5.6	4.7
% 65 years and older (July 1, 2016)	18.7	22.6	19.6	27.8	15.2
Bachelors Degree or more, age 25+	21.5	22	17.7	20.0	29.8
Median Income (2011-2015, 2015 $)	43,105	55,893	42,931	40,449	53,889
% Persons in poverty	14.1	10.1	11.8	11.2	12.7

(U.S. Census Bureau Quick Facts n.d.)

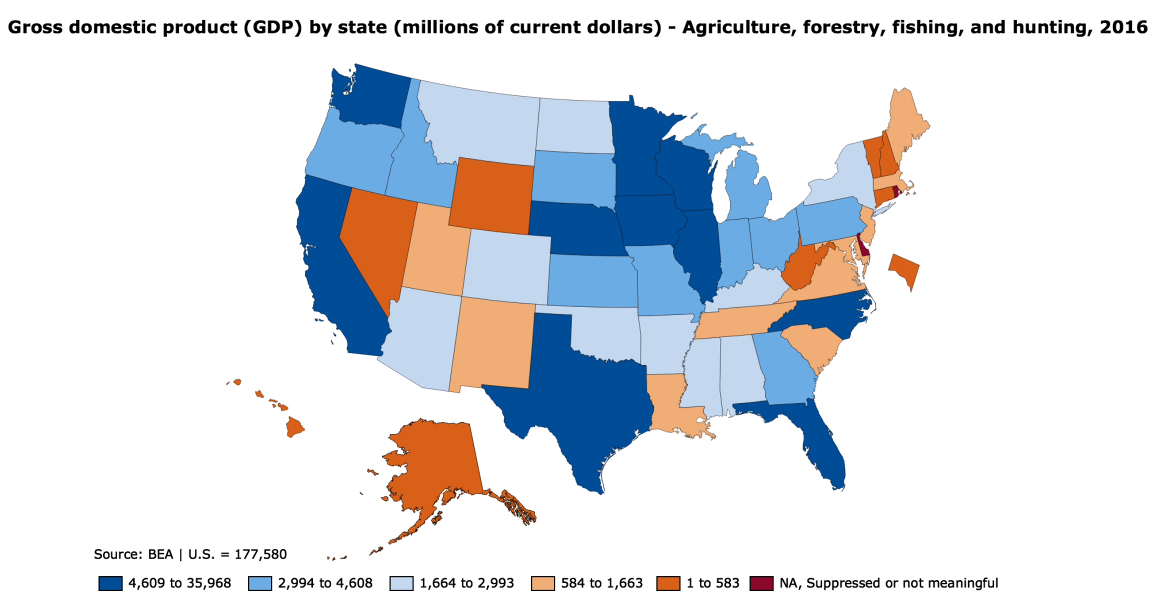


Figure 3.1. GDP for Agriculture, Forestry, Fishing, and Hunting by U.S. State, 2016 (U. S. Department of Commerce n.d.).

PHYSICAL GEOGRAPHY

The Great Plains of North America rise over 6,500' in elevation from 1,100' in the east to 7,800' in the west (USGS n.d.). The Republican River begins at around 5,000' in Colorado and terminates at just over 1,000' when it joins the Smoky Hill River to form the Kansas River (USGS n.d.). In Nebraska, the Republican River descends from an elevation of 3,600 – 1,400 feet west to east (Condra and Hall 1907, 8). Proportionally 30% of the basin is located in Kansas, 31% in Colorado, and 39% in Nebraska with a total area of 25,018 square miles (NDMC 2010; Figure 3.2). Its stream length is 453 miles, the drainage basin area is 16 million acres (NDMC 2010; USBR 2016) and the streambed is 200 - 400 feet below the uplands that define the valley (Condra and Hall 1907). The basin watershed discharges 395 cubic feet per second of surface water near Hardy, Nebraska at the Kansas border (N-NRC 1976). Eolian sand, loess, sand and gravel, shale, chalk, and limestone can be found throughout much of the region (USDA 2006).

Climatologically, the Plains of western Kansas and Nebraska and eastern Colorado for the Republican River basin are a combination of B, C, and D climates based on temperature and precipitation. The headwaters and far western half of the basin fall within a B climate (classed as semi-arid and arid), while the mid- and lower-basin fall mostly within a C climate (classed as humid sub-tropical); D climates (classed as humid continental) are possible (Figure 3.3).

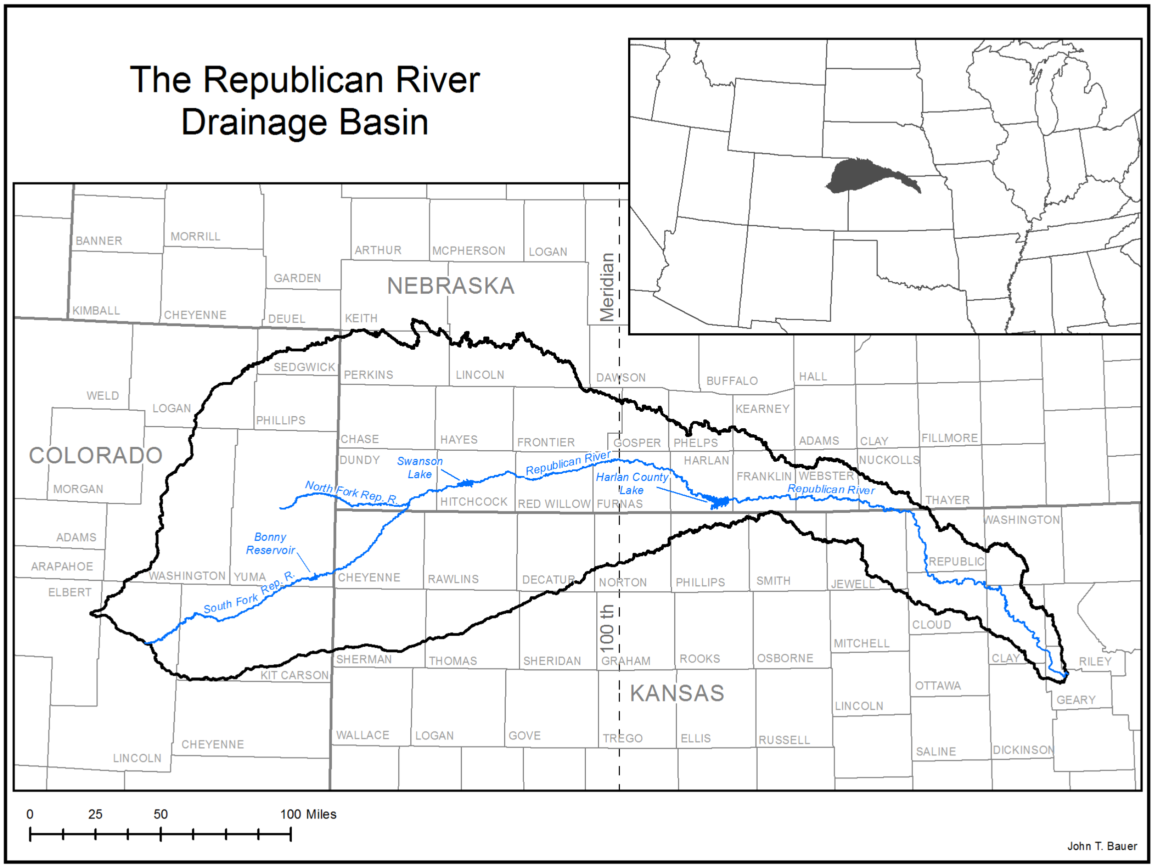


Figure 3.2. The Republican River Basin with the 100th Meridian (Bauer 2017).

The Republican River is considered a flashy-stream or prairie stream because it relies on annual and seasonal precipitation for its streamflow. Other atmospheric and climate factors that can impact precipitation and subsequent streamflow include dominant air masses, jet stream patterns, oceanic circulation, and atmospheric oscillations as part of a teleconnected system. These large-scale conditions create climatic and physical borders at the local scale that impact the basin's agricultural economy.

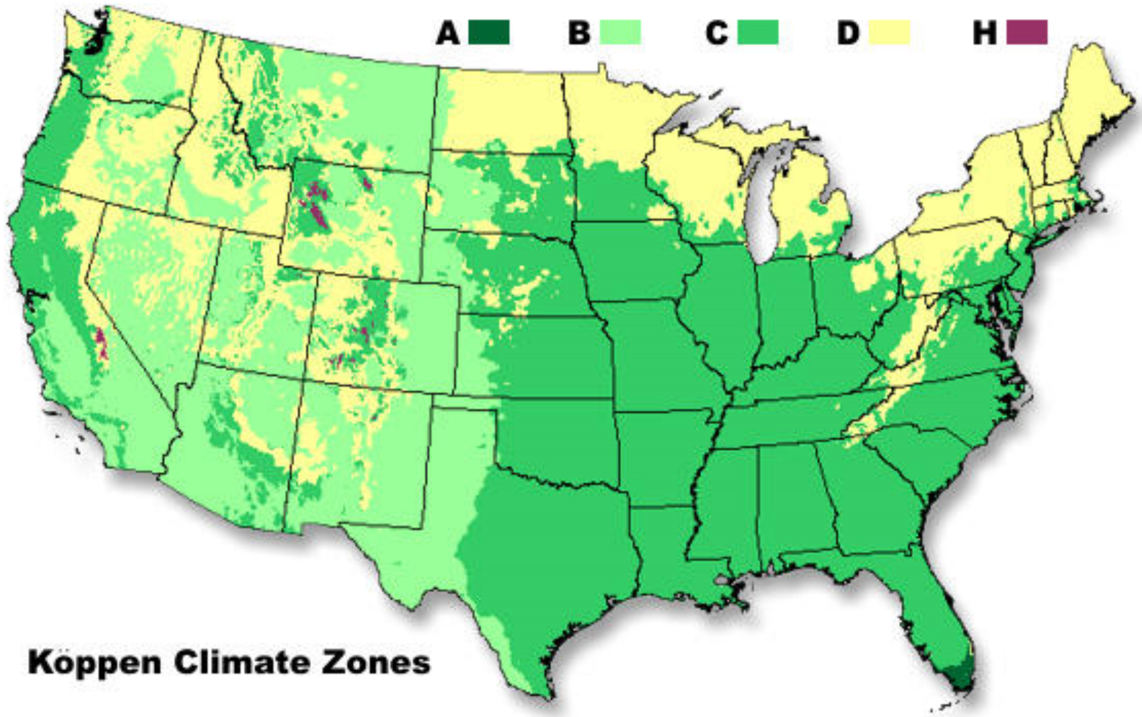


Figure 3.3. U.S. Köppen Climate Zones (NOAA n.d.b.).

The remainder of the chapter describes the irrigation districts, their governance, and the role of the U.S. Army Corps of Engineers (hereafter Corps) and the U.S. Bureau of Reclamation, relative to the three irrigation districts. Reclamation and the Corps oversee large areas of the Great Plains and its watersheds that include the Republican River. These two federal agencies have a vested interest in infrastructure, policies, and regional water decisions. The Nebraska and Kansas Bostwick and Frenchman-Cambridge Irrigation Districts are part of Reclamation, so its development is an important component of the basin's socio-hydrology.

The Irrigation Districts

The Nebraska and Kansas Bostwick and Frenchman-Cambridge Irrigation Districts inhabit a near contiguous narrow strip of the river valley and bottoms that are conducive to surface water irrigation (Figure 3.4). Socially they are rural foci for the basin's regional identity, offering steadfast agricultural characteristics and economic stability (Griggs 2017). The three districts' infrastructure and functionality are a social adaptation to the basin's environmental conditions of its climate, soils, and hydrology. For the agricultural growers of the basin, the districts are water commodified and water's market-value culture (Sherow 1990).

Figure 3.4. Republican River Basin, U.S. Highway 34, west of Cambridge, NE, irrigation canal in the foreground (Author).

Frenchman-Cambridge Division

Located in southwestern Nebraska, the Frenchman-Cambridge Division (FCID) is the western most district. It began in 1947 under the Pick-Sloan Plan; its dams and canals were completed by 1964 (USBR 2017b; Figure 3.5). It was the first completed Nebraska Reclamation project. There are a total of four major storage dams on tributaries and the Republican River's main stem. The division includes three irrigation districts: Frenchman Valley, Hitchcock and Red Willow (H&RW), and Frenchman-Cambridge (USBR 2017b). Reclamation maintains water storage use permits at its reservoirs for the district, and FCID contributes to the maintenance of the dams (Brad Edgerton FCID Manager pers. comm. 2016; USBR 2017b).

The district is largely linear for 110 miles varying in width from one to three miles (Bell n.d.). Its four major canals travel 156 miles helping subsurface water return flows for Harlan County Lake (HCL) and to stabilize groundwater (FCID n.d.). The four major dams located west to east — Enders, Swanson, Hugh Butler, and Harry Strunk — provide water for up to 66,090 irrigated acres along the Republican River and Frenchman and Red Willow Creeks; approximately 45,000 acre-feet of water (USBR 2017b). The Frenchman-Cambridge Irrigation District holds natural flow irrigation water permits for nearly 46,000 acres and has 41 direct flow permits, the oldest from December 22, 1890 to the newest November 13, 1987. With those permits the district is able to divert up to 531.5 cubic feet per second of natural flow as long as there is streamflow in the river (FCID n.d.); it is equivalent to 1,054 acre feet/day or 385,044 acre feet/year. If surface flows are inadequate, water releases from the Division's dams go directly into the streams and are then diverted to canals (Brad Edgerton FCID manager pers. comm. 2016; USBR 2017b). Some growers are able to access groundwater to supplement surface water as needed (Brad Edgerton FCID manager pers. comm. 2016).

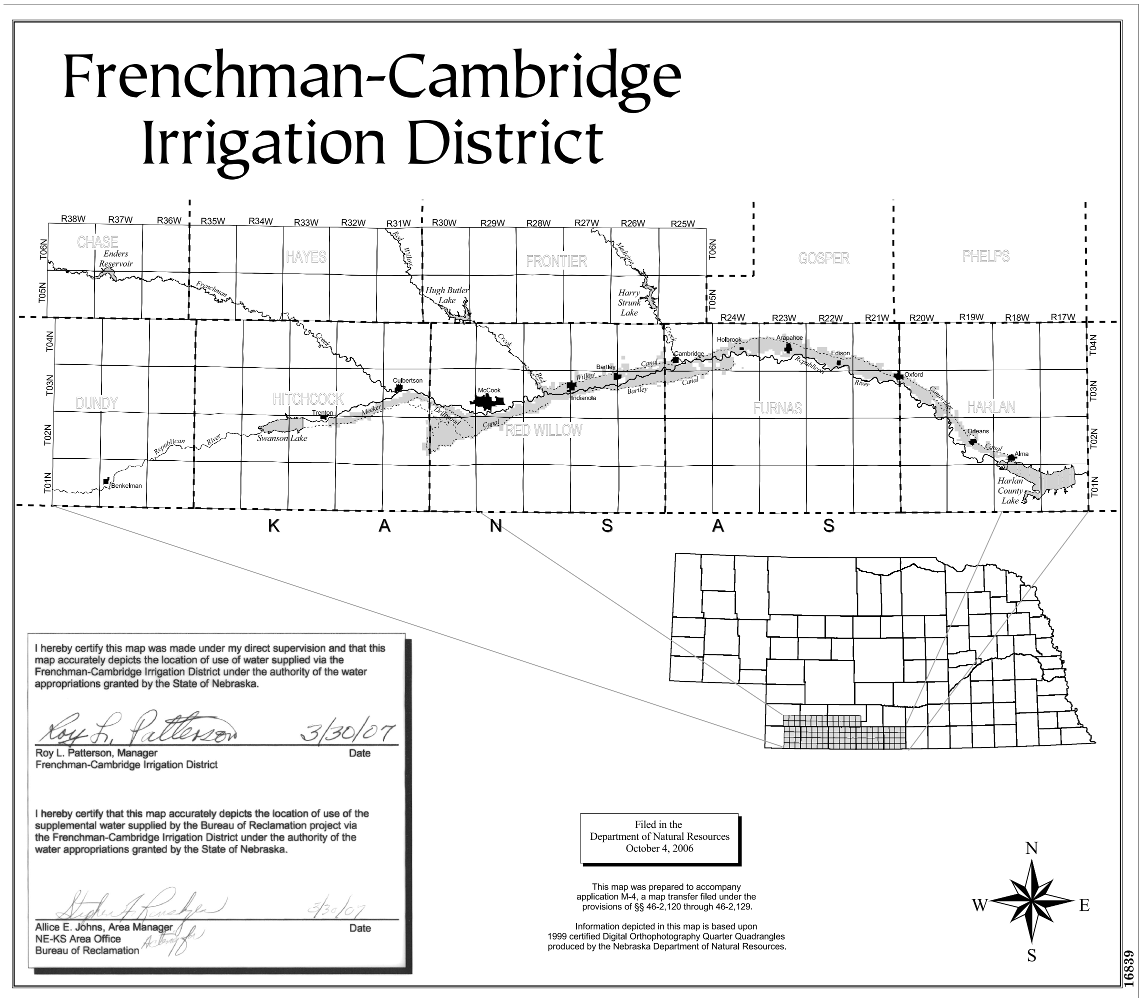


Figure 3.5. Frenchman-Cambridge Irrigation District (FCID n.d.).

BOSTWICK DIVISION

The Bostwick Division occupies south central Nebraska and north central Kansas and includes Harlan County Dam and Lake (built by Corps) and Lovewell Dam and Reservoir (built by Reclamation; Figure 3.6). The Nebraska portion is known as NBID, Nebraska Bostwick Irrigation District, and the Kansas portion as KBID, Kansas Bostwick Irrigation District. It contains one diversion dam (Superior-Courtland), and six pumping plants plus canals, laterals, and drains. The system serves up to 86,240 irrigated acres in Nebraska and Kansas with another 18,000 potential acres primarily in Kansas. System construction repayment plans by irrigation districts and their members were in place by 1951, and projects were completed by 1957. Water for the division is stored in HCL and Lovewell Reservoir. HCL has a 193,000 acre-feet irrigation capacity, and Lovewell's 24,930 acre-feet conservation pool provides irrigation water for KBID; both districts use water from HCL (USBR 2017b). NBID was the second completed state Reclamation project for Nebraska, and KBID was Kansas's fourth completed state project (USBR 2017b).

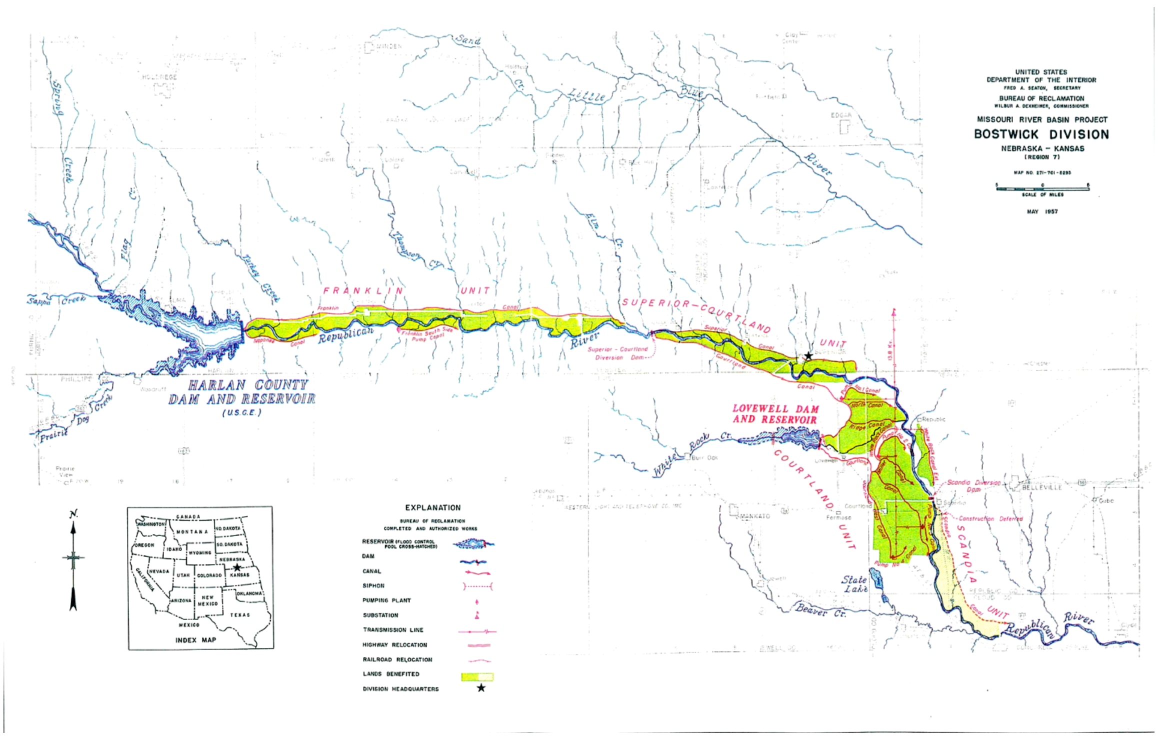


Figure 3.6. U.S. Bureau of Reclamation Bostwick Division. Nebraska and Kansas (U.S. Department of the Interior, Bureau of Reclamation 1957).

NBID has up to 20,492 irrigation acres, and includes two units (Franklin and Superior-Courtland). The Kansas portion has up to 62,000 acres for irrigation and one unit, the Courtland Canal (USBR 2017b). However, the number of actual irrigated acres is lower due to state water rights and certified permits (Tracy Smith NBID manager and Jared Giles KBID manager pers. comm. 2017; Table 3.2). Reclamation holds the water storage use permits for both districts at HCL and

Lovewell. It has contracts with both NBID and KBID to deliver irrigation water as needed when there is not enough natural flow (USBR 2017b; Mike Delka NBID manager pers. comm. 2016; Tracy Smith NBID manager and Jared Giles KBID manager pers. comm. 2017).

Table 3.2. Pick-Sloan Program, Republican River Divisions

	Bostwick Nebraska	Bostwick No. 2 Kansas	Frenchman-Cambridge*
Certified Irrigated Acres**	22,455	43,500	45,669
Water Storage	Harlan County Lake	Harlan County Lake and Lovewell Reservoir	Enders, Swanson, Hugh Butler, and Harry Strunk Reservoirs, plus smaller reservoirs
Canals, Diversions, and Pipe	~97 miles	~260 miles	~421.7 miles

*Not including Frenchman Valley or Hitchcock & Red Willow Irrigation Districts.
**On an annual basis districts may irrigate fewer acres. (U.S. Supreme Court 2012; Brad Edgerton FCID manager, Jared Giles KBID manager, and Tracy Smith NBID manager, pers. comm. 2017)

There is an improved understanding of the basin's hydrology since the Republican River Compact's origination along with improved technology. Both districts continue to use surface flows and stored water from HCL and Lovewell, but some NBID members are able to access groundwater sources because they occupy hydrologically advantageous locations over portions of the High Plains Aquifer (Figure 3.7). The KBID location at the far eastern end of the basin does not have the same groundwater access and the division is totally reliant on surface water flows from Nebraska (Jared Giles KBID manager pers. comm. 2016). At times those surface flows may be augmented from Nebraska's N-CORPE project, but are not available to NBID because they are used by Nebraska to meet their Kansas Compact water obligation (Mike Delka NBID manager pers. comm. 2016; RRCA n.d.c.). N-CORPE is a Nebraska augmentation management plan developed for surface flows in response to Kansas's litigation. Western and up-basin Nebraska groundwater pumping and subsequent declining tributary surface flows means less inflow to HCL and potentially less Compact water for either Bostwick districts. KBID's share of water in the Courtland Canal comes from HCL, so they are at greater risk of diminished quantities (U.S. Supreme Court 2012; Griggs 2017; NDNR n.d.).

IRRIGATION DISTRICT GOVERNANCE

Notably there are nine direct agencies or actors connected with water management, delivery, infrastructure maintenance, and operations, and surpluses and deficits for the three irrigation districts. Depending on environmental and political circumstances, their influence and power can be amplified or muffled by other actors and agencies. As an example, technical innovation gave rise to groundwater access and pumping in the basin beginning in the 1950s with rapid expansion into the 1970s. The growth of groundwater access shifted political influence away from surface irrigators and the Bureau of Reclamation and to groundwater irrigators (Aiken 1980). Surface water irrigators make up only 10% of the basin, tipping political power to the 90% of groundwater irrigators (Figure 3.8). In Nebraska, Natural Resource Districts and their governance boards regulate groundwater and appear to have greater influence than do the surface water

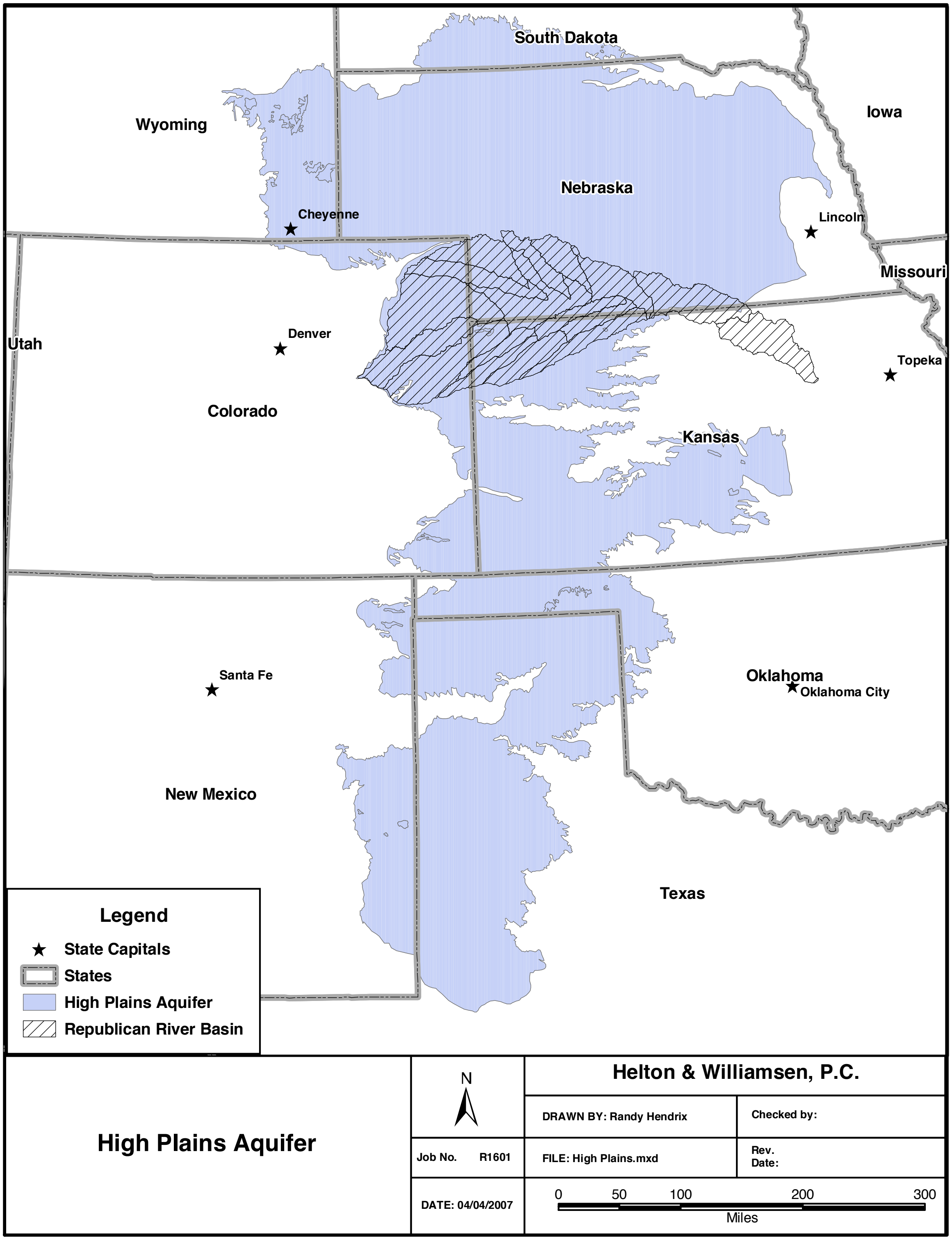


Figure 3.7. The High Plains Aquifer and the Republican River Basin. The Kansas Bostwick Irrigation District is in the only area without access to the High Plains Aquifer's groundwater (RRWCD n.d.).

irrigation districts with their federal Compact affiliation (*Frenchman-Cambridge Irrigation District v. Heineman*, 974 F. Supp. 2d 1264, D. Neb., No. 12-00445). A simplified relational diagram is found in Figure 3.9. These relationships are important because they contribute to an understanding of the basin's socio-hydrology. The relationships move backwards, forwards, or jump over actors to achieve desired outcomes, thereby spotlighting the basin's governance complexity.

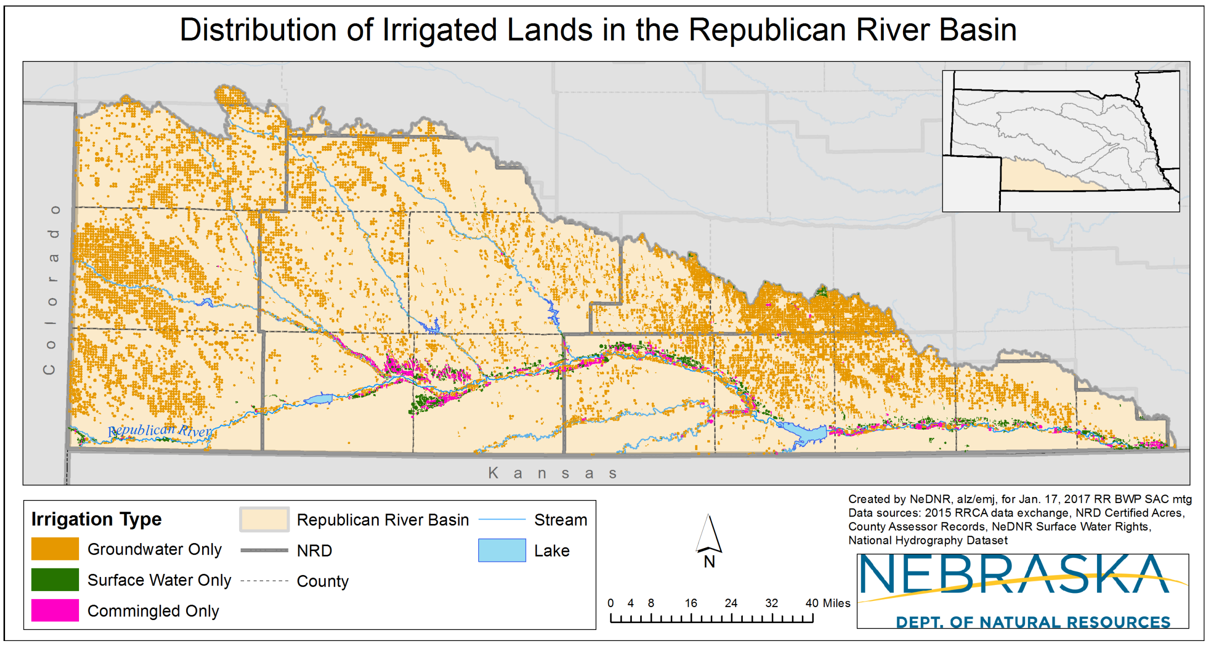


Figure 3.8. Nebraska Irrigated Acres, Republican River Basin (NDNR 2017).

All the irrigation districts are political subdivisions of their states. Each has a district manager or superintendent, a three-member Board of Directors elected on a rotating basis, and landowner irrigation district members. Directors and district members must own classified irrigable acres within the district. The superintendent has management authority for service and personnel, and advises the board. Districts are funded by assessed levies for classified irrigated acres that are paid with property taxes. They hold the surface water rights, and deliver irrigation water to their members when requested (*Kansas Statutes Chapter 42*, *Nebraska Revised Statutes Chapter 46*). The districts were developed in part to leverage irrigation potential within their state and provide economic stability to their agricultural communities via Reclamation and the Pick-Sloan Program. The stated mission for KBID is clear: "Kansas Bostwick Irrigation District No. 2 is to deliver the precious resource of water to our irrigators and agricultural producers in the most cost effective, efficient, and conservation minded way possible within the affordable limits of available modern technology" (KBID n.d.).

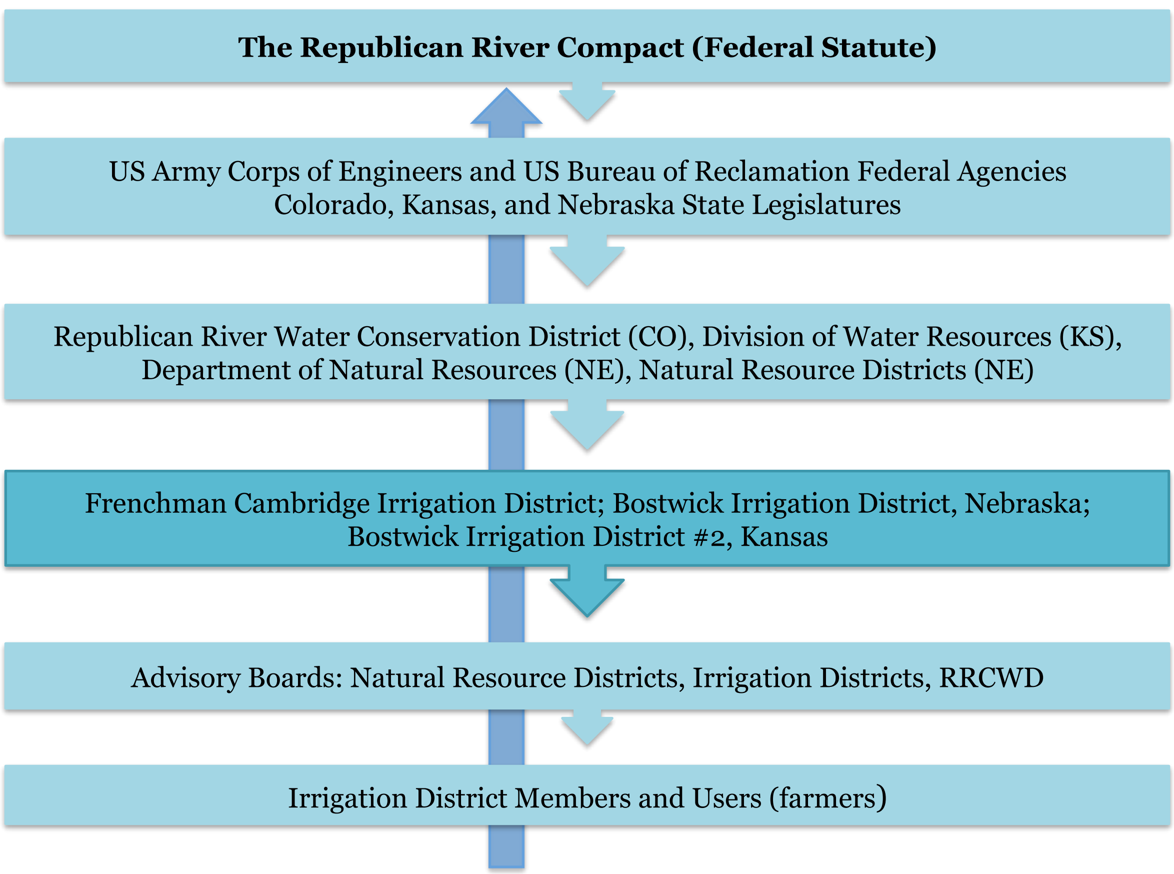


Figure 3.9. Republican River Basin Governance (Author).

History and Role of Federal Agencies in the Basin

Because the Republican River basin is in a semi-arid, water scarce environment, Reclamation along with state and local actors developed a regional water management plan in the form of irrigation divisions and districts. Those projects embody in part John Wesley Powell's vision of the West and how water from public lands should be harnessed for the greater economic good based on physical surveys and programs that emphasized community cooperation. He supported development in the semi-arid and arid West that took a watershed approach, forsaking political boundaries. Land parcels should be larger than 160 acres, but irrigated acres limited to 80. By using that metric in a water scarce environment, agricultural returns could be maximized. As such, he opposed the irrigated 160-acre designation for arid western farms connected to Reclamation dams and water believing those large acreages would not receive enough water for mature crop development (Stegner 1982; Worster 2001). The Republican River districts maintained the 160 irrigated-acre limit for its landowner irrigators (USBR 2017d) until the 1982 Reclamation Reform Act (Public Law 97-293) that increased acreages to 960 (USBR 2015c). Modern technology has made it easier to water 160 acres than Powell's era, but at a cost to the hydrological system. Knowledge of these historical relationships and situations help explain the current socio-hydrological realities of the basin in physical and social context. The Bureau of Reclamation and the Corps are discussed in more detail.

U.S. BUREAU OF RECLAMATION

The 1902 Newlands Act established the Bureau of Reclamation as part of the USGS and later the Department of Interior (Stegner 1982; Worster 2001; Benson 2011; USBR 2017d; Otstot n.d.). As the name implies, Reclamation's intent was to 'reclaim' land throughout the arid and semi-arid west that was considered ill-suited for settlement or agriculture, primarily through water development projects and management (Stegner 1982; Worster 2001). Reclamation addresses water scarcity through its mission to "manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public" (USBR 2017d). Today it oversees Western water for hydropower, fish and wildlife, water quality, recreation, water supply, irrigation, and flood control among other projects as it shifts to a water management oriented position and away from major construction projects (Benson 2011; USBR 2017d; Otstot n.d.). Reclamation's water projects are intended to benefit local nearby water users. Users reimburse the government for facility construction like dams and reservoirs, but the federal government retains infrastructure ownership (USBR 2017d; Otstot n.d.); the Republican River districts fall within this category.

Reclamation has five regional divisions in 17 states that include numerous dams, power plants, and projects (Benson 2011; USBR 2017d). The Great Plains region is the largest and includes all or parts of nine states. The region extends from the Canadian border to Texas' southern tip (Figure 3.10). Within regional borders are area offices, divisions, and units that are part of larger Reclamation projects.

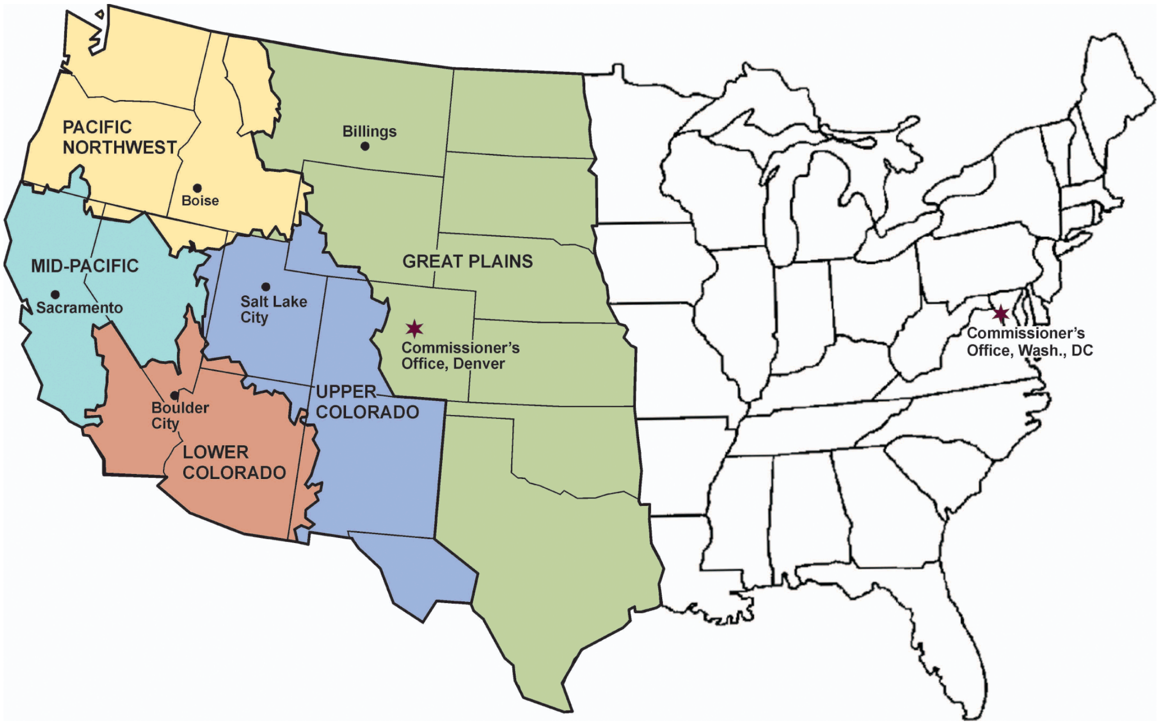


Figure 3.10. U.S. Bureau of Reclamation Regional Divisions. The Republican River is part of the Great Plains Division (USBR 2017c).

Reclamation's Pick-Sloan Missouri River Basin Program encompasses a large area of the Great Plains Region and includes the Republican River basin and its projects (USBR 2017a; Figure 3.11). Among the three Compact states, there are over 80 Reclamation projects, primarily in Colorado. In the basin, Colorado and Kansas have one apiece and Nebraska has nine (USBR 2015b). The Nebraska-Kansas Area Office contains the Bostwick and Frenchman-Cambridge Divisions and their units within the Republican River basin (USBR 2017a, 2017b).

Pick-Sloan Missouri River Basin Program

The 1944 Flood Control Act, also known as the Pick-Sloan Flood Control Act, focused specifically on the Missouri River basin region for water conservation, control and use. Its origins lie in the cyclical droughts and floods in the region before and during the 1930s. Initially two plans were developed for Congress. The Corps' Pick Plan, named after Col. Lewis A. Pick, followed Corps directives by emphasizing flood control and navigation. The Sloan Plan, named after Reclamation's William G. Sloan, focused on irrigation and hydropower. They were reconciled with the 1944 Flood Control Act, thereby providing for both navigation and irrigation in the larger Missouri River basin region (Knutson 2011; USBR 2015a, 2017d; Otstot n.d.; Rucker n.d.).

The Pick-Sloan Missouri River Basin Program focuses on beneficial surface water uses such as power, sediment control, water supply, flood control, and irrigation (USBR 2017d; Otstot n.d.; Rucker n.d.). Of the original 5.3 million acres identified for irrigation in the Missouri River basin, Reclamation has developed only 550,000 acres; 2.5 million acres were de-authorized and development of the remaining 2 million acres is unlikely (Otstot n.d.).

The Missouri River Basin's Reclamation hierarchy starts with the Great Plains Region that directs the Pick-Sloan Program and local area offices, who receive program and operational leadership from both. The Republican River basin's local area office is the Nebraska-Kansas office in McCook, Nebraska. The Pick-Sloan program includes multiple divisions that are often focused on irrigation or other water related activity. It assists two divisions in the basin, the Bostwick and the Frenchman-Cambridge Divisions. The Nebraska-Kansas Area Office manages those divisions and Reclamation's project water for ~264,000 farmland acres in the irrigation divisions, has ~56,000 reservoir surface water acres, and 75,000 acres of public use land (USBR 2017b).

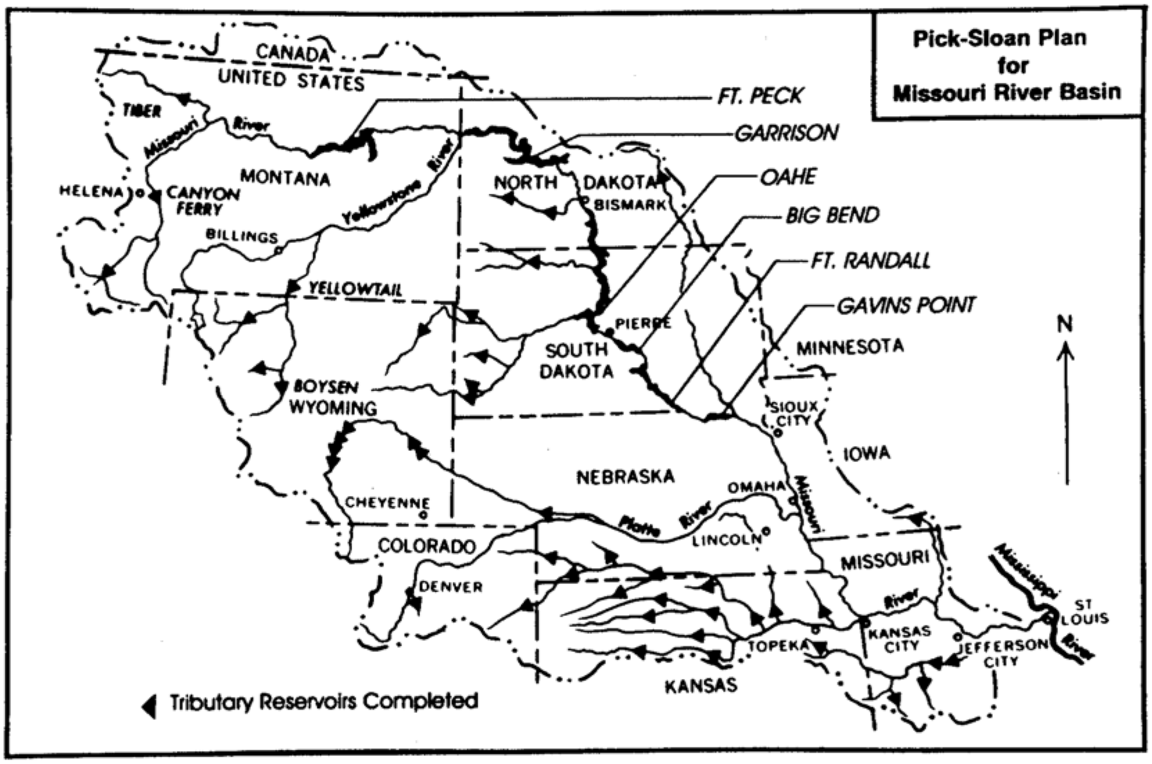


Figure 3.11. U.S. Bureau of Reclamation Pick-Sloan Missouri River Basin Program (U.S. Army Corps of Engineers, Office of History 1992).

Environmental conditions including floods, droughts, and insect infestations made economic and social order difficult for residents of the basin, as was true throughout the Plains states (Sherow 1990; Worster 2001; USBR 2017b). Reliable water was one solution to stability and economic survival. The Pick-Sloan Plan and its irrigation projects were a means to achieve it. According to the Nebraska-Kansas Area Office (USBR 2017b), project benefits include an agriculturally stable economy for growers of row crops like corn, alfalfa, silage, wheat, and hay, the elimination of crop failure (with available irrigation water), increased crop yields, flood control, and recreation. Compared to Kansas Bostwick, the two Nebraska districts have the larger share for basin farmland acres at more than 250,000.

U.S. Army Corps of Engineers

The Corps is focused on flood control, its main mission in the Midwest and Great Plains, and is a part of the basin's political and infrastructure system. The Republican River is in the largest of the Corps' eight divisions, the Northwestern or Lewis and Clark Division. It contains over one-fourth of the U.S. land mass and covers all or part of 14 states and has 35% of the Corps' water storage capacity (Figure 3.12). More broadly, civil projects and management are based on river basins, and reflect its flood control and navigation mission (USACE n.d.b.).

The Republican and Smoky Hill Rivers meet in Kansas to form the Kansas River, a tributary to the Missouri River. The Kansas River helps to maintain Missouri River navigation at Kansas City. Harlan County Dam and Lake on the Republican River in Nebraska is part of the Corps' Kansas City District. It is unique compared to the Corps other district projects because HCL contributes to and holds water for Reclamation's Bostwick irrigation projects in Nebraska and Kansas. It is the only non-Reclamation dam and reservoir in the Republican River basin. Water storage, releases and dam control are coordinated between the Corps and Reclamation. Like all reservoirs, waters held in HCL are divided into pools such as the dead pool at the bottom, the conservation pool in the middle where irrigation water is held, and the flood pool near the top (Hotchkiss 2011; USACE 2015). For HCL in particular, Reclamation controls the bottom 3 pools and the Corps the top 2.

The Corps can trace its history to the Revolutionary War although its formal establishment occurred in 1802. Historically they provided civil and military infrastructure, but more recently their mission has expanded to include environmental issues, including water resources development. That shift can be traced to the 1964 Wilderness Act that moved the Corps away from large-scale water and irrigation projects and towards recreation, at the same time maintaining flood control. The Wilderness Act also led local beneficiaries of federal projects, like irrigators, to take on more infrastructure and fiscal responsibilities and encouraged states and other local actors to play a greater role in development and management of water projects (USACE n.d.c.; Sabatier et al. 2005). In the Republican River basin, it has meant that irrigation districts and their users are responsible for a percentage of the costs required for facilities operations and maintenance (Mike Delka NBID manager; Brad Edgerton FCID manager; and Jared Giles KBID manager, pers. comm. 2016).

Figure 3.12. U.S. Army Corps of Engineers Northwestern Division. The Republican River is part of the Kansas City District (USACE n.d.b.).

SUMMARY

The number of actors in the Republican River basin provides a glimpse of the socio-hydrological complexity of the region and its irrigation districts. Power dynamics, perceptions of nature, management, shifting consumer demands, unpredictable weather and water delivery each have a role in constructing the basin’s socio-hydrological profile. How those perceptions and actions have been formed has a long history that can be traced to Western writers and thinkers from the ancient Greeks and Romans to later and contemporary scholars such as George Perkins Marsh, David Lowenthal, and Erik Swyngedouw. No matter the era, people’s relationship to and with water remains central to understanding our social and hydrological evolution. Chapter 4 further explores the components of the basin’s socio-hydrology with a discussion of water, water law, and the Compact.

Chapter 4
Water, Law, and the Republican River Compact States

To the uninitiated, water is simple. It rains or snows, is absorbed into the soil, and fills up streams and lakes. More than any other natural resource, water is one of the planet's most necessary resources. Powered by the Sun's energy and gravity, the hydrologic cycle globally transports and transfers water for people, plants, and animals that depend upon a reliable and predictable water source. When those sources decline in quantity, degrade in quality, or delivery becomes less dependable, people search out other sources through technological innovations, migration, or legal agreements such as interstate compacts that safeguard access to water.

Understanding the environmental conditions of the Republican River valley and its states, types of water, and the laws and policies that developed in response to water availability and use is important for constructing a picture of the socio-hydrological relationships that exist. Chapter 4 provides the canvas upon which those relationships can be placed in temporal and spatial context. The first section begins with an overview of the region and basin's physical characteristics, its settlement, and need for water. Second, three different types of water rights and their origin are discussed; they can apply to both surface and groundwater. Third, because groundwater was not well understood until later, a separate section details its history, types of use, and various restrictions. Fourth, each Republican River Compact state's water history and legal evolution is overviewed. Specific details about state statutes that inform water policies and practices are found here; these are not exhaustive, merely representative of major water events. Fifth, the origin of interstate water compacts is discussed along with how the Compact fits within the federalist system while maintaining their Compact commitment. The conclusion points to challenges including population changes and governance issues that will require the basin states to carefully assess their resources and associated future water demands.

HISTORICAL AND CLIMATIC CONTEXT

On the Great Plains and in the American West, water plays a significant climatic role. Consider the regional precipitation distribution. Weather systems travel from the west eastward over the Rocky Mountains, creating lush windward regions on western slopes and dry leeward rain shadows on eastern slopes and the Great Plains. On the Plains, precipitation becomes less predictable, especially west of the 100th meridian, a common demarcation for the 20” (51 cm) isohyet and tilled agriculture; the 98th meridian is also used (Bleed[1] 1993; Schlager and Heikkila 2011). The Great Plains western corridor annually receives 20” (51 cm), while the eastern corridor’s annual average is 36” (91 cm); in both locations 80% occurs in the fall and spring (Bicek 2002). Less than 20” often requires supplemental water often from irrigation (Griggs 2012; Figure 4.1). The spatial distribution and large drainage basins of major western rivers gives some hint of the region’s precipitation pattern, and its impact on Plains and Western water use and law.

[1] Ann Bleed served as the state hydrologist, Deputy Director, Acting Director, and Director for the Nebraska DNR from 1998-2008.

Figure 4.1. U.S. Annual Precipitation, 1961-1990 (National Atlas of the United States 1970).

The 1862 Homestead and 1877 Desert Land Acts encouraged more migration and settlement in the Great Plains (Figure 4.2). Migrants brought with them eastern agricultural practices, crops, and their water needs. As they traveled onto the Central and High Plains and made greater incursions to the mountainous interior, reliable water grew scarce. Rivers were infrequent, wells were expensive, snow pack and storms were unpredictable, and the climate itself was more hostile that its eastern counterpart. Despite claims that the rain follows the plow, the enticement of free land, Gilpin's assertions of effortless agriculture via artesian and underground water, plus other beguiling shenanigans (Stegner 1982; Manley 1993; Griggs 2012), settlers found the reality somewhat different. William Gilpin, with 25 years of experience in the West and the Colorado Territory's first governor, was a fervent promoter of westward expansion even though much of what he advocated was inconsistent with western reality (Stegner 1982). John Wesley Powell was one of the few to refute Gilpin's and others' claims about the West with scientific data and personal experience (Stegner 1982), but for those choosing to materialize the country's manifest destiny, water would be a necessity. Regardless of motivations and desires, some habits are hard to relinquish. Agriculturally what worked in the east was not going to work in the semi-arid and arid West (Stegner 1982).

Figure 4.2. The North American Great Plains Region (UNL Center for Great Plains Studies 2017).

Ioris (2013) argues that it is the socio-natural interdependencies and the historical and geographic routes chosen by people that have shaped water valuation. People prioritize routes that give them access to water. They convey greater value to routes that follow rivers especially in semi-arid and arid regions over those that do not. On the Great Plains those routes would include the Oregon, Mormon, and California Trails that paralleled the Missouri, Platte, Sweetwater, Snake, and Humboldt Rivers that blazed their own trails through the plains and mountains. While some migrants would stay the trails' entire course to their final destination, others would find and settle intermediary places near or along tributaries. Those choices and results are "a political statement that synthesizes mechanisms of cooperation and competition between individuals and social groups for the allocation, use and conservation of water" (Ioris 2013, 323). As someone who promoted water cooperation, Powell would have supported Ioris' conclusion. The 1902 Newlands Act and the Bureau of Reclamation's establishment applied the ideas of water cooperation and competition to help manage the West's water (Stegner 1982). The Bureau of Reclamation itself was established in part to turn perceived fruitless lands of the Great Plains and West into productive agricultural holdings with the help of dependable water from federal water storage and delivery projects (Stegner 1982; Manley 1993; Worster 2001). With later exceptions like the groundwater boom, communities and Reclamation projects shadow those early trails along the rivers and their offshoots. They assign value and power to the region's water, visibly marking the landscape.

Great Plains and Western states' water policies and laws evolved due to one, previous experiences in and with Eastern water laws and customs, and two, local circumstances such as climate, water scarcity, and mining that could be at odds with Eastern choices. Legal rulings and jurisdictional control could either follow Eastern riparian practices or incorporate new practices. For the Great Plains states of Kansas and Nebraska, settlement typically occurred on their eastern half first, where water is somewhat more reliable. Applying Eastern riparian rights (creating water diversions on land adjacent to a water course) seemed logical, as did using the 100^{th} meridian as a precipitation border between a wetter east and drier west (Griggs 2012). The 1944 Flood Control Act used the 98^{th} meridian, and others used a north-south transect through Kansas City for political water borders (Dellapenna 2004; USBR 2016). However, the western half of the Great Plains states developed a new methodology for dealing with water, prior appropriation. Here water rights are prioritized by earliest usage date and can be traced to the California and Colorado gold rushes, diffusing west to east as the interior became more settled. In some ways, the 100^{th} meridian became a border for not just water but water policy. I discuss both riparian and prior appropriation water rights in the next section.

Today, U.S. states may have a combination of riparian, prior appropriation, or other water rights frameworks for both surface and groundwater as property that can result in complicated water laws, interpretations, and applications (Zellmer and Harder 2007; Craig 2012).

TYPES OF WATER RIGHTS

Whether surface or groundwater, water on the earth's surface is subjected to social control through laws and policies and the use of dams, canals, and subsurface pumping. Water quantity fluctuates spatially and temporally requiring users to address excesses and shortages, as is the case with contested interstate compacts (Zellmer and Harder 2007; Craig 2012; Griggs 2017), as well as among individuals and others with conflicting water rights. Understanding how water regulation changed from Eastern riparian rights to Western prior appropriation rights is important for understanding the Republican River basin's socio-hydrology.

Water and water rights are closely tied to how water is defined hydrologically and legally. Except in Texas, groundwater belongs to a state and its citizens, and the *use* of water can be granted to individuals, companies, or municipalities as a private property right. State legislatures enact water laws that are implemented and enforced by state agencies that issue water use permits under specified guidelines.

The U.S. states' surface and groundwater water laws function under one of three systems: riparian, prior appropriation, and hybrid. According to Getches (2009), twenty-nine states use a version of riparian rights, nine states are subject to prior appropriation including Colorado, and ten states use a hybrid system that works toward integrating older riparian practices with newer appropriation methods, including Nebraska.

Riparian Water Rights

Riparian rights focus on land adjacent primarily to streams, where owners of riparian land have the right to divert water onto the property, use it for beneficial use including irrigation, and are responsible for reasonable use. Riparian users cannot cause harm to other rights holders regardless of regular or naturally diminished flows, upstream or downstream (Aiken 2003a; Peck 2007; Getches 2009; Jones and Cech 2009; Craig 2012). Some water storage is possible with small dams and ponds as long as it meets a state's reasonable use standards (Getches 2009). The courts have addressed reasonable use standards (Graham 1992; Dellapenna 2013). Watershed limitations restrict transfer of riparian water outside its natural boundaries, although states can make exceptions (Getches 2009). Even though Nebraska is a prior appropriation state, it is currently pursuing the possibility of transferring excess Platte River riparian surface flows during floods into the Republican River basin as a means to both store water and have water on hand for Kansas (Potter 2017; Raun 2017a). Riparian rights are impacted by population increases and associated water demands, affecting change in statutory regulations that manage the public's water interests. Riparian rights can also be lost, but usually not from non-use, rather time limits, permit regulations, or eminent domain seizures (Aiken 2003a; Getches 2009; Jones and Cech 2009). While these rights are effective in the East, they are not practical west of the 100th meridian with less surface water reliability, so a new method evolved, prior appropriation.

PRIOR APPROPRIATION WATER RIGHTS

Prior appropriation rights focus on initial time of use, the "first in time, first in right" doctrine; the quantity of water being diverted; and actual water application for beneficial use. These rights differ from riparian water rights because the property receiving water is not required to be adjacent to the stream. Hess (1916) and others documented this American practice to the 1848 California gold fields and miners who desired some protection for their mineral claims.

> The objects of the codes of the early Californians…were to secure, within practical limits, equality of right and opportunity in acquiring and operating mines, and to define justifiable property in natural

> resources. To best accomplish this, *he was made first in right of property who was first in time of possession, and his utilization of that right gave him a valid claim against all others except the nation. Discovery, followed by appropriation, was recognized as sanction of title, and a specific measure of use or development of the property thus acquired was requisite to its retention* (4). (Emphasis in the original)

Diverted water as a natural resource became part of the mining claim, as long as it and the other resources were beneficially and continuously used. Eventually water applied for agricultural production came under the same code. The code allowed senior and junior rights holders to be identified and resources allocated, setting up winners and losers especially during low surface flow periods and extended droughts. Water rights owners can sell their rights and buy others that may be more favorable, since the water right is not attached to the overlaying property or land. The 1877 Desert Land Act, that prioritized state water laws, and California's interpretation that federal land sold to private individuals included the federal water rights strengthened prior appropriation practices in western states (Getches 2009; Jones and Cech 2009).

Like riparian water rights, appropriation water rights can be lost due to failure to meet statutory permit requirements. They are generally defined as a property right with the following attributes: a priority date, a use quantity, a specific point of diversion, a specific place of use, and specific type of use such as irrigation. The first two attributes are fixed, and the latter three can be changed subject to state law requirements (Getches 2009; Jones and Cech 2009; Griggs 2017). In some states and instances, riparian rights have been merged into appropriation rights as vested rights, that is the riparian rights predate an appropriation rights statute, as is the case in Kansas (Getches 2009).

Created water, or water beyond what naturally occurs from precipitation for example, can come from pumped groundwater for a trans-basin diversion or transfer, for example. Water in excess of natural flow can be used without restriction by the entity that generated it. As an example, Nebraska uses supplemental groundwater from its N-CORPE project (pumped groundwater) to enhance surface flows in the Republican River to meet Compact compliance and make sure that Kansas receives its allocation (Hendee 2016; Griggs 2017; N-CORPE 2017).

Hybrid Water Rights

Hybrid water law systems merge riparian and appropriation practices to reflect their state's historical and contemporary water uses. Most states using hybrid systems began with riparian rules, but they eventually adapted prior appropriation rights to include riparian components, blending the water philosophies together. There is no single doctrine for states using hybrid systems. Depending on a state's laws, hybrid systems may or may not work well in places that have climatic and physical characteristics that reflect arid and wet regimes within a single political border. California, Nebraska, Oklahoma, and Texas have hybrid systems based on their states' beliefs about how land and water rights are or are not connected. However, Colorado and other states have contended that one, water law is a state issue, two, federal patent, or land, has no riparian rights within a state because state water law overrules federal practice, and three, land and water rights are conjoined with federal land sales, so if federal land is sold it includes the water right (Getches 2009). The 1866 Mining Act and 1870 Placer Act clarified that vested and accrued appropriation rights as state law per local customs and laws were valid. Each state is free to determine how riparian rights can be validated and used before new state appropriation statutes take effect (Getches 2009).

Hybrid systems face four challenges. First, riparian rights can require continuous flow while appropriation depends on water used. Second, courts have struggled with hybrid systems during shortages when riparian users are required to cut their use, senior appropriators take their full entitlement, and junior rights holders carry the loss burden (Getches 2009; Jones and Cech 2009). Nebraska does allow for competing riparian and appropriation legal challenges based on reasonableness and the 1895 Nebraska Irrigation Act (Getches 2009). Third, senior riparian dates are typically earlier than appropriation dates because of newer statute implementation dates, putting junior appropriators at the most risk (Getches 2009; Jones and Cech 2009). Fourth, riparian rights must be part of a stream's final determination of water rights, including past used and unused riparian rights, although states can make exceptions to un-used rights (Getches 2009; Griggs 2017). In the Republican River basin, Nebraska has hybrid water policies, while Colorado and Kansas use prior appropriation for both surface and groundwater.

GROUNDWATER

Groundwater presents a unique situation since it has been difficult to access through time, and it is invisible to most people. Because surface water is easily visible and easily available, surface water laws developed first. The previous section discussed types of state water laws that pertain to surface and groundwater. However, groundwater development requires greater scrutiny, particularly as it relates to Western water compacts, surface water, and irrigation.

Western federal statues were in favor of groundwater prior appropriation by the early 1870s (Hess 1916; Getches 2009). Colorado (1876) and Wyoming (1889) included prior appropriation in their constitutions and six other western states have either constitutional or statutory elements for it (Peck 1995, 2007; Getches 2009; Jones and Cech 2009). Since many of the western states had longstanding local practices that endorsed prior appropriation, its inclusion was logical and reasonable to ensure and maintain rights currently afforded a state's residents.

Today groundwater in the Republican River basin plays a larger role than it did when the Compact was written, when all growers in the basin were primarily surface water irrigators or dry land farmers. The three Compact states face problems noted by Craig (2012) for unlimited use and storage, proportional use, identifying hydrological connections, and exacerbated aquifer depletion. These take the form of augmentation plans, reservoir use and storage, Compact allocations, the Republican River Compact Administration groundwater model, and groundwater pumping. Science and technology have allowed growers to tap groundwater in uplands that were once inaccessible or too expensive for drilling irrigation wells. Poorly understood hydrological connections are now under scrutiny (Bentall and Shaffer 1979; Harnsberger and Thorson 1984; Moody et al. 1989; Aiken 2006; McGuire 2009; Konikow 2013; Castle et al. 2014; KGS n.d.).

As a result of these changes and increased water use, tensions between surface water and groundwater users exist, as do inconsistent water regulations and management. Understanding the origin of groundwater and the laws that govern it is helpful for discussing the basin's past, present, and future water uses.

Groundwater Sources and Extraction

Two zones, the zone of aeration, basically soil, and the zone of saturation, basically rock, have a role with groundwater. Each of the two zones stores water and overlaps to some degree with the other; each has varying degrees of porosity, permeability, and gravitational resistance. Some groundwater can be in the zone of aeration, but the majority is found in the zone of saturation due to gravity; water typically percolates down through the zone of aeration. The water table is a commonly identified border that marks the point where the pores in the zone of aeration or saturation are "full" and the water pressure and atmospheric pressure are equal. The water table fluctuates depending on the amount of water in the ground at any particular time and the local geology and topography. Aquifers are usually below the water table and within the zone of saturation in areas that are permeable. Their access depends on location and geologic conditions like an aquiclude that can prohibit easy water transport. Water makes it way to an aquifer during its formation or by rainfall and snowmelt. In the later cases, those sources recharge the aquifer, adding water to it (Getches 2009; Jones and Cech 2009; DeBlij et al. 2013; Korus et al. 2013; Marshak 2013). If water in an aquifer is extracted by groundwater pumping, it can be replaced by water percolating back in over time, or recharging it. Hutchins defined groundwater water rights "as all water in the ground that is free to move by gravity, is capable of being extracted from the ground, and is susceptible of practical legal control. Necessarily excluded from this category is subsurface water that is not free to enter wells" (1955, 157).

Intensive groundwater well use can negatively impact aquifer volume. Wells are used to access groundwater for economic reasons like municipal water use or agricultural irrigation (Figure 4.3). Drilling and maintaining wells are expensive operations depending on well depth, ongoing use, and costs. Prior to the 1950s when wells were often hand dug to shallow aquifers, the advent of high capacity pumps accessing deep aquifers allowed irrigation systems such as center pivots to flourish and deliver more water more efficiently than windmills (Manley 1993; Schafer 1993; Kromm 2011; Korus et al. 2013).

Pumping water from wells creates a cone of depression or influence where water is absent until it is replaced. Depending on physical factors, geological conditions, and well distribution, cones can impact other users, reduce available water, cause subsidence, or salt water contamination (Getches 2009; DeBlij et al. 2013; Korus et al. 2013; Marshak 2013). How many users have access to an aquifer is important because withdrawals may or may not be regulated, and the impact on individual users will vary, as will incentives for sustainable use (Figure 4.4).

In many states, water falls within the public trust doctrine for its residents. As long as they abide by the state's rules and regulations, people can use the water. The challenge presented by groundwater is balancing its sustainability against its use, so that the resource is not degraded or depleted to such a degree that it can no longer be used as a private property right. In the case of agricultural production and groundwater irrigation, less water due to aquifer declines could result in increased operating costs to dig deeper wells, or more regulations to ensure future water availability.

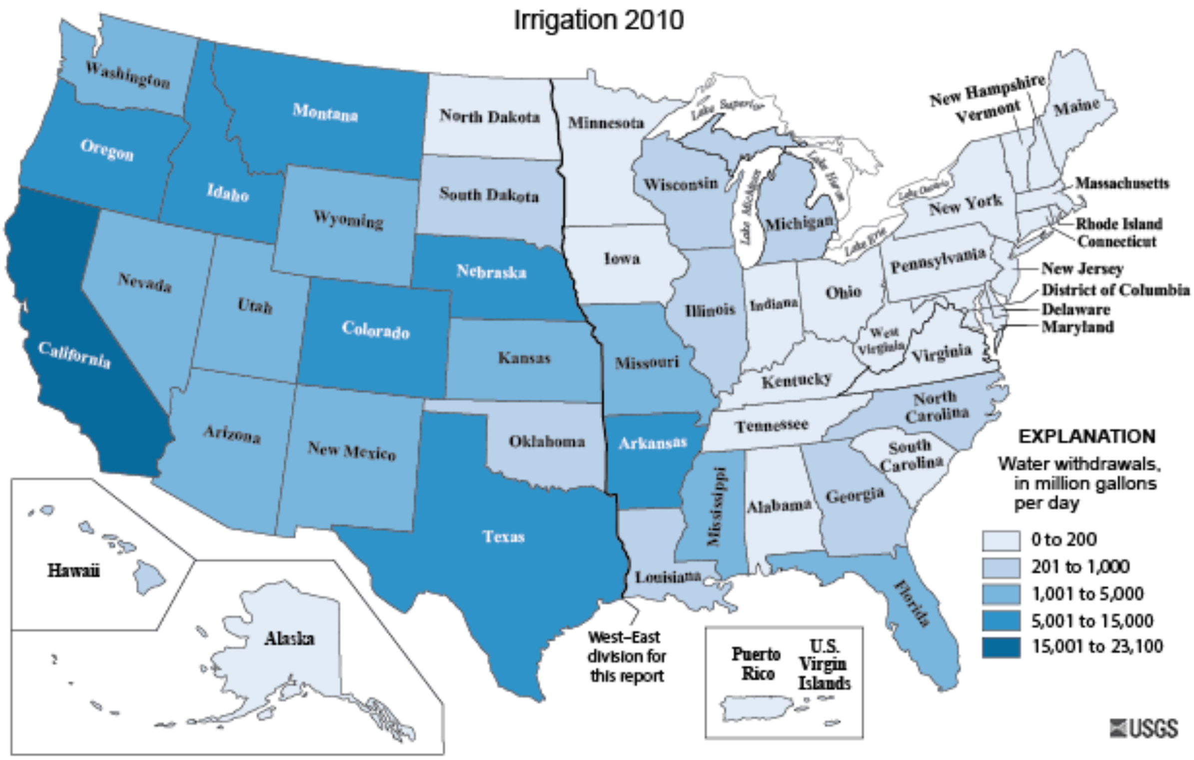


Figure 4.3. U.S. Irrigation Surface and Groundwater Withdrawals, 2010 (USGS 2016a).

Aquifer increases and declines are based on their physical location, geology, and seasonal activity. A group of hydrologically connected aquifers is known as a groundwater basin. Groundwater basins may be connected to a stream, and groundwater withdrawals can affect streamflow. Additionally, the groundwater is considered a tributary to the stream (Getches 2009; Jones and Cech 2009; DeBlij et al. 2013; Marshak 2013). If withdrawals exceed recharge rates, the aquifer's ability to maintain historical levels is compromised, and natural recharge may not be enough (Getches 2009; Jones and Cech 2009; Korus et al. 2013). For the Republican River and Compact, the hydrological connectivity between streamflow and groundwater/aquifer are critical to individual rights, state statutes, and state allocations. The RRCA's Groundwater Model assesses stream base flows and connectivity of groundwater withdrawals (RRCA n.d.a.). It provides a means for the states to monitor streamflow and aquifer rates, so that each state can adjust their water behaviors appropriately to maintain compliance. Model development was a response to the 1998 lawsuit against Nebraska alleging water over use, especially groundwater, and the impact it had on surface flows to Kansas for KBID.

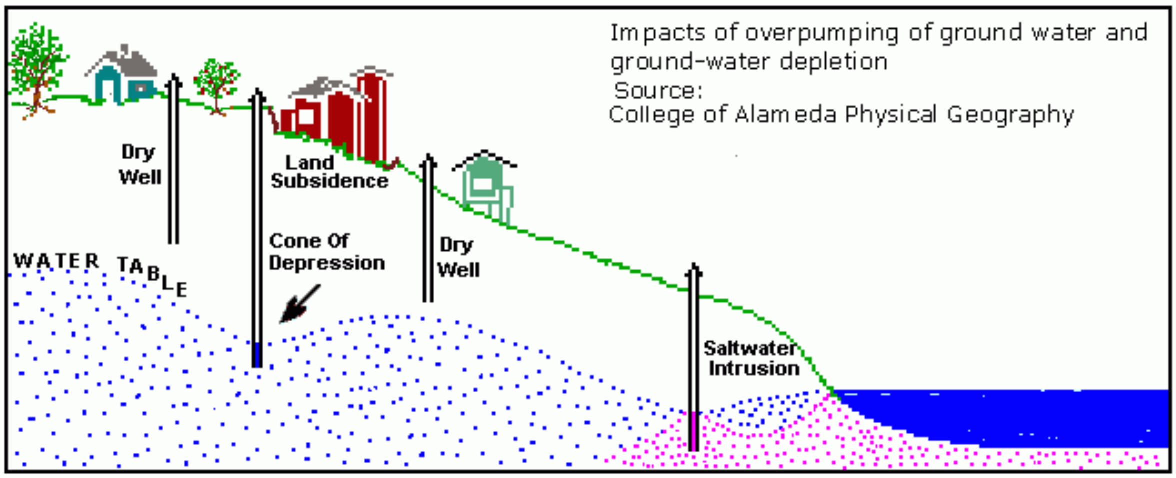


Figure 4.4. Cone of Depression Impacts (USGS 2016b).

<u>LAWS, LIABILITY, PERMITS, AND LIMITS</u>

Groundwater rights can be one of three types: prior appropriation rights, reasonable use or correlative rights, and rule of capture rights. The last two are based on land ownership. Groundwater prior appropriation is similar to surface water with no injury requirements, permit systems, and reasonable use levels (Aiken 2003b; Peck 2007; Getches 2009; Craig 2012). Kansas and Colorado are prior appropriation states setting prior appropriation reasonable use levels (Getches 2009; Jones and Cech 2009). The second rule, reasonable use or correlative rights are attached to land ownership; Nebraska uses this doctrine. Shares of the water can be proportional to land owned, and use of the water cannot hinder other owners' water rights or use. In Nebraska, reasonable use limits for groundwater are set by local NRDs (Aiken

2006; Gless and Longo 2008; Getches 2009). As a public resource, controls are usually through a permit system administered by a state agency, so that states can protect competing users and make allocations in the public interest (Getches 2009; Jones and Cech 2009). The rule of capture or the English rule, the third rule, allows a land owner exclusive and unlimited rights to water underneath their property including water in the soil. The rule of capture has been modified by better hydrological science and state legislative action (Getches 2009); none of the Compact states engage rule of capture rights.

Five rules or categories define groundwater liability or causing harm to other users according to Getches (2009):

- No liability. If groundwater is a property right, then a user can pump as long as there is no harm to existing users.
- Prior appropriation/Junior-liable. New users are liable if senior vested rights are harmed. States modify appropriation laws to limit protections.
- Reasonable use doctrine/American rule. If unreasonable use occurs, a landowner may be liable; if correlative rights are used, shortages are proportional.
- Restatement (Second) of Torts 858. Liability occurs if withdrawal causes unreasonable harm to others, exceeds an individual's reasonable share, or affects a water course, lake or its users.
- Economic reach. A balance between senior and junior rights, e.g., considers economic costs, competing use values.

A sixth rule or category is prior appropriation/senior-liable or the no injury rule. Senior users cannot modify their rights in a way that harms a junior user, since the junior's rights are based on water conditions at the time the permit is issued (*K.S.A. 82a-708b*). States use these rules in groundwater disputes based on their own statutes and practices.

Economics has a role in groundwater development and use as a management tool. Economic costs may be internal where the user carries the burden or external where others such as utilities and the public bear the burden (Getches 2009). Those costs can be mitigated and shared depending on how laws and policies are designed by a state for either permitting or liability. Permits in particular provide a means of regulatory development that can embed user rights as well as benefit society. States use statutes to define groundwater, how it can be accessed, whether permits are required, and when penalties are imposed (Getches 2009; Jones and Cech 2009).

Drilling (well) and use (water right) permits are typical for groundwater and both may be required. Drilling permits are required in advance of actual well sinking with specific prerequisites such as geologic structures, type of use, construction type, and location. Use permits are dependent on whether or not a new well will impair current users. Hydrological data, value, and political judgments by agencies about the merits of a permit, statutes, and policy goals contribute to the decision. Successful permits need to be implemented in a reasonable amount of time and water beneficially applied. As is the case with surface water permits, they can be lost due to inactivity or improper use (Getches 2009).

Pumping restrictions are often set to protect current and future groundwater uses, usually by state statute. Nebraska NRDs set groundwater withdrawals and timeframes rather than a state agency (Gless and Longo 2008; Getches 2009; Bleed and Hoffman Babbitt 2015). Depletion levels are set for a "socially optimal" period that represents current policy priorities (Aiken 2003b; Getches 2009; Jones and Cech 2009). What is socially optimal will and does change with time and circumstances, setting in motion new conflicts. Critical groundwater areas can be identified by states. Usually these are locations where depletions are severe and recharge rates lag significantly. In those areas groundwater drilling and pumping are under strict regulation as is the case in the tri-basin states (Aiken 2003b; Getches 2009; Jones and Cech 2009).

All three Compact states contain critical groundwater areas that are bound by aquifers or basins; each has different criteria. In Nebraska's Republican River basin, they have four NRDs that control groundwater use. Statewide, Kansas has 12 IGUCAs and one LEMA, none of which are in their portion of the Republican River basin. Kansas's upstream Republican River basin is in a portion of the Northwest Kansas Groundwater Management District #4 (KDA 2016b; Griggs 2017). Colorado statutes call for reductions based on priority (Getches 2009; Jones and Cech 2009; Griggs 2017).

CONJUNCTIVE USE AND STORAGE

State laws across the U.S. often govern surface and groundwater separately, even though they may be hydrologically connected. Such practices are shortsighted and cause undue confusion for permit holders and users, the agencies that administer state policies, and injure the resource itself (Gless and Longo 2008; Griggs 2012, 2017). Conjunctive use refers to joint management or use of surface and groundwater under hydrological conditions or for maximum efficiency (Aiken 2003b; Getches 2009; Jones and Cech 2009). Recognizing the connectivity between surface and groundwater, some states have shifted to a single management system, encouraging water rights holders to use both sources if they have access, or by regulating vested rights. The 1973 Report of the National Water Commission and the 1998 Report of the Western Water Policy Review Advisory Commission both recommended single system management for effective, efficient, and realistic policy (Getches 2009). Colorado and Kansas generally adhere to a single-system practice, unlike Nebraska, which uses separate systems for surface and groundwater.

In the Republican River basin Colorado and Kansas mostly use an appropriation water system for surface and groundwater[2], so joint management occurs as a matter of course. Nebraska maintains separate surface and groundwater systems with some joint projects such as Integrated Management Plans (IMPs) for specific groundwater basins like the Republican River. IMPs require the Nebraska Department of Natural Resources (NDNR) and river basin NRDs to develop joint water management plans. Without conjunctive management, lag times occur for streamflow, recharge, and depletions. These become problematic for both users and the states. On the ground, conclusively demonstrating hydrological connectivity is hard and expensive (Getches 2009; Jones and Cech 2009). Groundwater well pumpers do not want to stop pumping if their wells aren't connected to surface water and they hold senior appropriation rights, especially considering streamflow time lags and negative crop and economic impact.

One solution to lag times is bypass pumping and another is augmentation. Bypass pumping is a substitute groundwater supply that can meet the needs of

[2] In Colorado, basin groundwater is alluvial (or tributary) and directly connected to the stream itself, or it is designated and attributed to other distant streams in the basin.

senior rights holders while maintaining surface flow. An augmentation plan typically sources groundwater to replace surface water for surface water users. Augmentation can take the form of diversions, storage, and new sources (Getches 2009; Jones and Cech 2009). In each case, substitute water can be supplied to senior surface-users that decrease their surface impacts while letting juniors continue pumping groundwater. Bypass pumping has physical limitations, while augmentation can allow for storage and later releases, as one example (Getches 2009).

Storing groundwater for future use can take place with surface reservoirs or pumping water into aquifers. Both systems require technological, infrastructure, and management strategies and cause some degree of environmental harm. Surface storage structures lose more water than underground ones due to evaporation, seepage, and pollution (Getches 2009). In the Republican River basin, augmentation pipeline plans have been instituted by Colorado (Colorado Compact Compliance Pipeline) and Nebraska (Rock Creek and N-CORPE) to keep both states compliant with the Compact and Kansas. The projects pump groundwater and pipe it to a designated delivery point in the basin to maintain surface flows to KBID (RRWCD 2009; N-CORPE 2017).

The second part of the chapter highlights each state's water law and policy development through time and places the Compact within those settings.

THE COMPACT STATES AND WATER POLICIES

Conflicts were inevitable at multiple scales due to the complex relationship between people and nature on the Great Plains with periodic droughts, sometimes poor water rights enforcement, water over-use, and over-allocation. At the macro scale, interstate water compacts became a common mechanism to mediate and pro-actively allocate water among states in the region. The 1943 Republican River Compact among Colorado, Kansas, and Nebraska is an example.

The basin spans different physical geographies and political boundaries setting in motion water resource issues, transboundary conflicts, and complex socio-hydrologic interactions. Water usage today is dependent on past population and agricultural uses. Each state has its own water history filled with indigenous, historical, and anecdotal chronologies that detail the meandering route water and politics have taken in an attempt to navigate murky hydrological relationships.

Prior appropriation is Colorado's water history, while Nebraska's and Kansas's began as riparian and changed to prior appropriation. Each of the states has its own social, climatic, and hydrologic landscape that influences water management and policy. Some portions are drier or wetter than others and were settled sooner or later than others. Thus, which water practice, riparian or prior appropriation, best serves the state and its water rights users is contingent upon physical conditions, traditional practices, and current behaviors. In the 19th century, John Wesley Powell was well aware of the conflict between the semi-arid and sub-humid conditions of the larger region. He supported water usage approaches that addressed the differences through his promotion of drainage basins as political areas rather than the Cartesian methods favored by unfamiliar easterners, legislators, and bureaucrats (Stegner 1982; Figure 4.5).

A state's early water experiences shape internal relationships between neighbors and external relationships with other states. Public resource management is difficult at all scales in time and space. As the Compact states matured, their water laws and policies were re-examined for appropriate modifications and clarifications. Each state's water history and legal development are presented in the following sub-sections. The discussions are not exhaustive; rather they provide an abridged explanation of events that shape their waterscapes. They begin by identifying the state's water laws and their jurisdictional administration in a single paragraph. It is followed by a physical description and a more inclusive overview that touches upon major events, legislation, and litigation.

Figure 4.5. John Wesley Powell's Drainage Districts. The far western corner of the Republican River basin is in red on the middle right side of the map; it is the Colorado portion of the basin. Extending the area east to the arid boundary would place the border near Medicine Creek and Cambridge, NE (Schulten n.d.).

COLORADO

Colorado's 1876 constitution embedded prior appropriation as the state's water law for surface and groundwater; in 1882, it was clarified by the Supreme Court as the state's exclusive doctrine in *Coffin v. Left-Hand Ditch Co*. Colorado makes groundwater distinctions that can be complicated due to hydrological relationships, legal language, and rulings. Except for de-regulated groundwater, those complications and challenges along with permitting processes are primarily the jurisdiction of Water Courts. Water Courts are part of Colorado's district court system and their chief responsibility is to oversee water issues within their water district; districts are structured around major river basins. The State Engineer in the Colorado Division of Water Resources Office works in conjunction with the Water Court on some issues, such as permits and unappropriated water (Schroeder 1991).

COLORADO WATER LAW HISTORY

Colorado's physical geography encompasses much more variety than either of its eastern Kansas and Nebraska neighbors. Its geography bisects the state into north-south regions with sweeping high plains in the eastern third and mountainous terrain in the central and western part of the state; high desert lands, mesas, and the Colorado Plateau add another landscape element. The state's basic physiography contributes to another layer that influences the waterscape of the state, the diverse precipitation regions. The state's annual precipitation can range from 0" to over 50" (0-127 cm) with the western slope and higher elevations typically receiving more than the eastern Front Range and Plains as well as the Western Plateau Region (Colorado Climate Center 2107). However, overall Colorado is considered to have a semi-arid climate. These and other diverse physical characteristics contribute to the state's waterscape and influence its water law and policy practices.

Colorado's water policy history is different from that of Nebraska and Kansas, primarily due to its more varied physical landscape and the 1859 Gold Rush. Successful agriculture depended on irrigation networks. Irrigation projects and other water practices existed long before 1859, such as Hispano settlers who adapted Spanish and Mexican water laws (Romero 2002). It was Colorado's gold rush more than anything else that presaged Colorado's 1876 constitutional inclusion of prior appropriation water rights. Supporting prior appropriation events include the 1859 Miners Courts and Claims Club who instituted "first in time, first in right" based on California gold mining practices (Romero 2002; Jones and Cech 2009). Two, irrigation diversions on all the major streams in the Upper South Platte Basin by 1861, helped by the Colorado Agricultural Society's determination to dispel the Great American Desert image (Jones and Cech 2009). Three, the 1874 Eaton School House meeting between upstream Cache la Poudre Fort Collins users and downstream South Platte Union Colony (Greeley) users — they settled without using their rifles (Jones and Cech 2009).

In 1882, the Colorado Supreme Court in *Coffin v. Left Hand Ditch Company* asserted Colorado's water law foundation, prior appropriation, to make it clear that Colorado was an exclusively pure prior appropriation state. Justice Helm wrote that riparian rights were not appropriate, or applicable, to Colorado considering its climate and economy and that prior appropriation is the water law of the land (Romero 2002; Getches 2009). All riparian rights were ultimately deemed ill-suited to Colorado's realities (Jones and Cech 2009).

TYPES OF COLORADO WATER

Between 1881 and 1969 the Colorado legislature clarified water conflict procedures focused on claim dates and priority listing, since water rights could potentially be considered newer than actual usage. Two important acts govern current policy: 1) the 1965 Ground Water Management Act that focused on specific areas for ground water management but did not consider natural streamflows, and 2) the 1969 Water Rights Determination and Administration Act that incorporated wells that were outside the 1965 areas. Both acts responded to groundwater conflicts in the South Platte and Arkansas River basins, groundwater pumping technology, and better alluvial aquifer and surface flow science (Getches 2009; Jones and Cech 2009).

The 1965 Ground Water Management Act addressed designated groundwater, defined as non-tributary water. Basically, it means groundwater that does not act as a tributary to a stream's natural flow (it is physically separated), and it can include other water that is not already appropriated for surface water rights (Jones and Cech 2009; Schroeder 2013). The 1969 Water Rights Determination and Administration Act addressed tributary groundwater. Tributary groundwater is water that is significantly hydrologically connected through surface streams and alluvial aquifers (Jones and Cech 2009). Tributary water is administered with the prior appropriation doctrine; a modified prior appropriation is used with non-tributary water (Schroeder 2013). Colorado's General Assembly legislated additional clarifications for non-tributary groundwater in 1985 and 1996 that addressed aquifer withdrawal rates, tributary standards, and modifications for four aquifers in the larger Denver Basin because of the area's economic importance (Schroeder 2013). In 2005, the General

Assembly enacted the Colorado Water for the 21st Century Act that includes an Interbasin Compact Committee (Rettig 2017a).

All surface water and underground water that is tributary to all natural streams, water seepage, wastewater, return flows, floodwater, springs, mine water, and groundwater is the property of the public (Schroeder 2013). A water appropriation is for a specific amount of water for beneficial use. It is gained after first, a conditional water right is perfected, and second, a water right is granted for the use of a specific portion of the state's water in priority. A conditional water right has to show beneficial, non-wasteful use, and as a vested property right is subject to forfeit (Schroeder 2013). Both the conditional water right and the water right have to be confirmed by adjudication by a district Water Court. The state then awards a water appropriation from the State Engineer at the Division of Water Resources (Schroeder 2014). Water rights are not generally appurtenant to land with some exceptions, once a right has been perfected it can be transferred and its use changed. Regardless, it must be beneficial, reasonable, appropriate, and efficient (Schroeder 2013).

Colorado water law has one basic water rule, tributary water, and three exceptions: non- and not non-tributary water, designated groundwater, and exempt wells. Relevant to this discussion are non-tributary and designated groundwater. Tributary water is basically the water in the state that is hydrologically connected, whether surface or groundwater. Non-tributary waters are not directly hydrologically connected or do not influence a stream; they are spatially distant or their aquifers have barriers that prevent hydrological connection. Second, designated groundwater is an alluvial aquifer without streamflow (there is no significant hydrological stream connection to the aquifer) (Jones and Cech 2009). These are groundwater areas located in the eastern High Plains of the state, and they broadly have no or minimal impact at the surface, so a modified prior-appropriation method is employed (Jones and Cech 2009).

Colorado Permits and Water Court

Colorado has no public trust doctrine, so the state does not hold some of its resources in trust for public use over private property ownership. For example, a landowner can determine how surface water is utilized if the property underlies a body of water or stream; they have the right to control access to surface water for recreational use like fly fishing or kayaking. As usual, permitting and challenges need to be administered. Challenges in Colorado take place with state district courts or by the State Engineer, unlike Nebraska and Kansas that use state district courts. Water Courts, as part of the district court, settle disputes through referees and judges in one of seven divisions (river basins) with enforcement by the state engineer or representative (Getches 2009; Jones and Cech 2009; Schroeder 2009; Figure 4.6). Water Courts encompass all or part of the counties within the water division. They have extensive jurisdiction in their division that range from water and conditional rights, augmentation plan approval, and approving water use outside of Colorado. The Water Court focuses on overseeing that no harm or injury is caused to other parties. Like the other states, water right applications include legal descriptions, initiation dates, amount of water claimed and its proposed use; a water referee investigates the process (Schroeder 2014). Importantly for water rights cases, well permits are not property and may be amended, but the water decree (claim and priority date) is the water right (Getches 2009; Jones and Cech 2009).

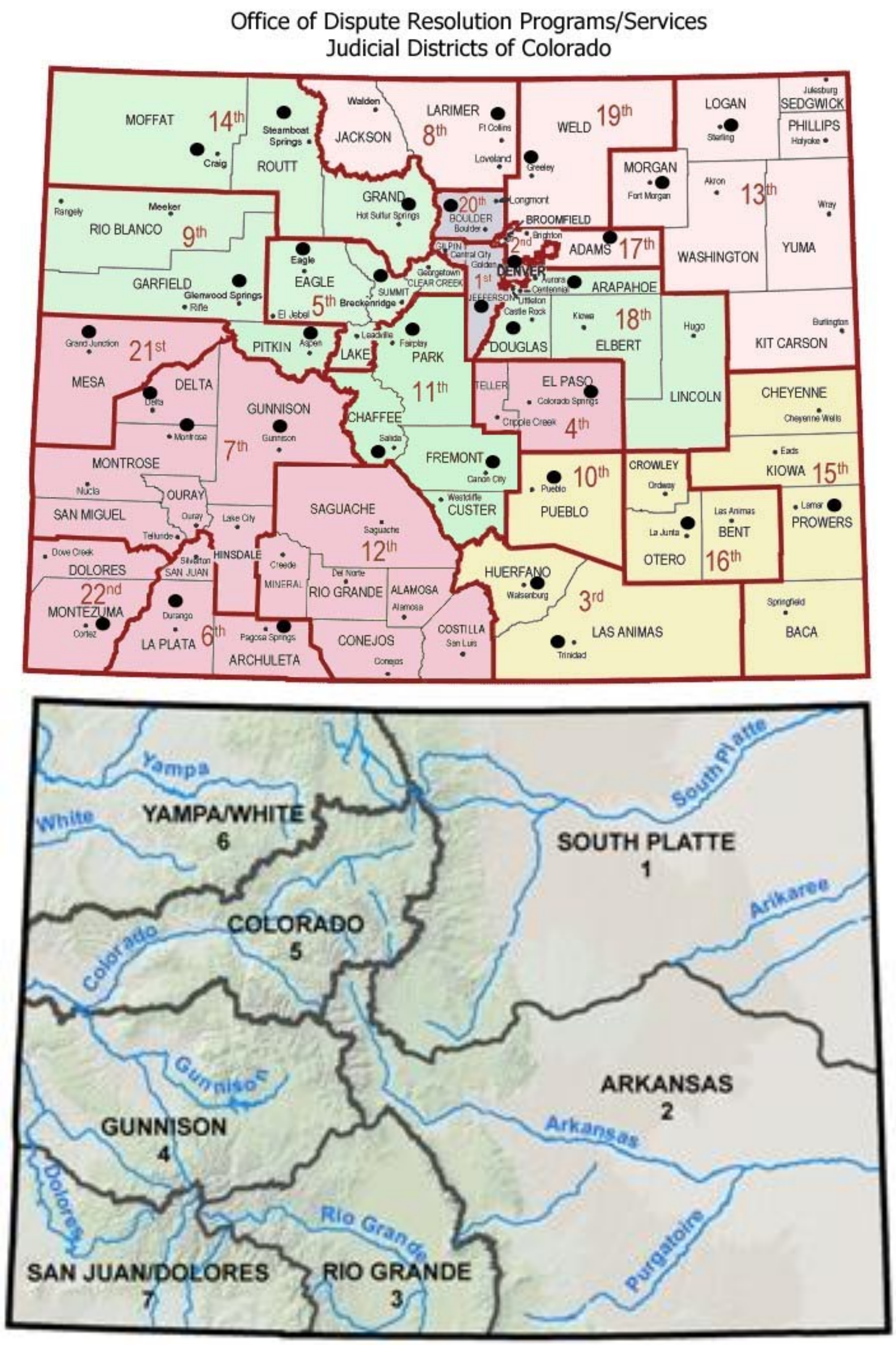


Figure 4.6. Colorado Judicial Districts (top) and Colorado Water Districts (bottom). The Republican River is in the 13th Judicial District and the South Platte Water District (Colorado Judicial Branch n.d.; CDWR n.d.b.).

Executive control for water sits primarily with the Governor's appointment of a State Engineer to the Division of Water Resources. The State Engineer, Division of Water Resources (DWR), and the Water Commission administer, distribute, and regulate state waters based on statutory authority and in conjunction with Water Courts. The Colorado Water Conservation Board coordinates water districts, evaluates water projects, develops legislation, and lobbies the legislature (Romero 2002; Getches 2009; Jones and Cech 2009). The State Engineer and DWR reviews and approves well permit applications after Water Court approval, orders the discontinuation of a diversion for non-beneficial use or senior priority rights, releases improperly stored water, and orders the installation of gauges, meters, and other devices. The DWR has also ordered, delivered, and dumped concrete into diversion head gates as reminders (Schroeder 2009).

Colorado Litigation and Interstate Compacts

The 1907 U.S. Supreme Court decision in *Kansas v. Colorado* over the Arkansas River was the first federal lawsuit where neighboring states, and later the federal government, claimed control over Colorado sourced rivers and waters. The Court's ruling asserted the doctrine of equitable apportionment, by which the Court has the power to apportion the water supplies of an interstate basin. Although the Court did not actually apportion the Arkansas River and dismissed the suit, the contentious relationship between the states has continued; it is discussed more fully in the later Kansas section. The 1922 *Wyoming v. Colorado* suit over the Laramie River was more complicated because the federal government filed *U.S. v. Colorado* for control of Laramie River water on federal land in Colorado (Romero 2002; Jones and Cech 2009). Federal rights were asserted over state rights for federal land (Romero 2002; Jones and Cech 2009). The Department of Interior's upstream embargoes to protect unappropriated water on the Upper Rio Grande River in Colorado, on the North Platte River in Wyoming, and the Salt River in Arizona to protect later downstream development alarmed upstream states and their ability to develop water within their borders (Griggs 2017). In addition, the Reclamation was making claims on unappropriated water on the Arkansas River and the North Platte River as an additional party to the *Kansas v. Colorado* and *Nebraska v. Wyoming* cases, respectively (Griggs 2017). It appeared that federal rights trumped state rights for federal land (Romero 2002; Jones and Cech 2009); state sovereignty only went so far. Furthermore, Colorado sources water for 19 downstream states due to its geographic position and the snow packed Rocky Mountains. Colorado's internal water policies will continue to be influenced by other states along with federal actions and agencies. For Western and Great Plains states the end result of these challenges among each other and federal agencies became interstate water compacts as a method to mitigation water conflicts and ensure water to each state.

California was the first to adopt prior appropriation in 1855. Colorado's prior appropriation doctrine, the Colorado Doctrine, and its legal choices served as models for other western states. Its focus on water rights and laws on security, reliability, and flexibility means the state was positioned to adapt over time to environmental changes as well as those taking place economically and demographically (Romero 2002; Getches 2009; Jones and Cech 2009). On a policy front, Gallaher et al.'s (2013) analysis of Colorado water laws and policy recognizes the state's adaptability and development of new policy tools under a variety of changing conditions.

However, they also state that the prior appropriation system constrains the adaptive capacity of the state, since old and new issues will demand concurrent attention.

Kansas

Since 1945, when Kansas passed the Water Appropriations Act (KWAA), it has used prior appropriation water rights for both surface and ground water with a vested rights process for pre-1945 water rights holders. From 1861 to 1945, it recognized riparian water rights for streams and absolute ownership for groundwater (Peck 1995). The Division of Water Resources Chief Engineer, the Kansas Water Office, and the Kansas Department of Health and Environment have jurisdictional control for water use, development, monitoring, and enforcement in Kansas as dictated by legislative action. The Chief Engineer carries considerable responsibility for issuing, evaluating, and enforcing water use practices to include water rights permits, regulating reasonable water irrigation quantities, certifying permits, overseeing conflicts and transfers, and minimum streamflows among many other water permit related issues.

A more expansive description of Kansas's water law and policy development begins with a short physical description, touches on early differences between eastern and western state water practices, and then focuses more fully on legislative commissions and the move to full prior appropriation. Also included are challenges to the KWAA, interstate compacts, and new concepts for dealing with the state's water.

KANSAS WATER LAW HISTORY

The derivation of the name *kansas* has a somewhat mixed legacy. Frequently it is ascribed to the Kansas River and the dominant indigenous group present during early periods of exploration. There are numerous spellings, as many as 125, such as Kansie, Canzon, and Kau or Kaw (a French option for the indigenous population). The different definitions could be "smoky" associated with the Kau or Kaw, another for "winds" or "wind people," and a third, *cansar* of Spanish origin meaning to molest or harass. In the end, it was Illinois Senator Stephen A. Douglas and author of the Kansas-Nebraska bill who thought if fitting to name both states after major rivers in their respective states, the Kansas and Nebraska Rivers, even though the indigenous members of Nebraska called the river the Platte (Schoewe 1954).

Like its northern neighbor Nebraska, the rolling hills, denser tree cover, and more humid climate of eastern Kansas, transitions to a flatter plain, expansive horizons with scattered tree stands, and a drier climate in the west. Physiographically it is part of the United States' Interior Plain, the eastern one-third of the state part of the Central Lowlands and the remainder assigned to the Great Plains (Schoewe 1949). "The number and density of streams in Kansas is directly related to the precipitation of the state" (Schoewe 1951, 264) and with a range of 40" (102 cm) in the southeast to 16-17" (~41 cm) at the state line with Colorado stream density should not be surprising (Schoewe 1951; Peck 1995). The range in precipitation and stream density also speaks to water usage and practice in those contrasting climatic regions, thereby influencing water law and policy through time.

Kansas's legal water history like many states that bridge the Great Plains and the West is one where older and familiar methods do not fit into new and different spaces. It begins with the state's eastern settlement patterns and common law riparian rights for stream water, whereby land ownership conveyed water ownership, and the courts settled user conflicts. Groundwater policy of this earlier era gave landowners absolute ownership to make withdrawals without regard to how it might impact neighboring landowners (Peck 1995, 2004; Rogers, Powell, and Ebert 2013; Styron n.d.). Many, if not most, water users of the time did not have documentation of either their water usage or had made no legal filings that recognized their groundwater rights and consumption (Peck 1995). The Kansas Territory had accepted riparian rights as early as 1855. By 1866 the territory was using prior appropriation in western Kansas. In 1868 it adopted common law for surface and groundwater, and legally recognized Western prior appropriation in 1878 (Sherow 1990; Griggs 2012; Rogers et al. 2013). In 1886, they adopted a weak form of prior appropriation requiring users to file their claim and post a sign but without any specifics like amount used (Sherow 1990).

TWO WATER SYSTEMS AND THE KANSAS WATER APPROPRIATIONS ACT

Western Kansas's adoption of prior appropriation is in part the result of diffusion from Colorado and other western states along with surface water scarcity and community values. These opposing policies within Kansas were suitable for the climatic conditions each region of the state experienced, and co-existed until the 1943 Republican River Compact. The Compact helped set in motion full adoption of prior appropriation along with the 1944 Kansas Supreme Court's mandate for a special focus on statewide groundwater (Griggs 2012).

James Sherow's *Watering the Valley: Development Along the High Plains Arkansas River, 1870-1950* (1990) provides an insightful and thorough analysis of irrigation water development in the Arkansas valley, the hydrologic and legal relationship between Colorado and Kansas over the river's waters, the river's ecological niche and response to increasing irrigation diversions, the culture of its residents, economics, and the role of law in developing water resources.

Dominating nature and market-culture values reinforced the commodification of water in Kansas's early water history throughout the state, and legal developments reflected these priorities in prior appropriation, riparian water rights, and later interstate compacts. The development in the Republican River parallels that of the Arkansas, but at a different scale and with different conditions. Importantly, conflict and cooperation between states and users for water was inevitable not just on the Arkansas, but throughout the state given that "the prior appropriation system fixed a commodity value to river flow" (Sherow 1990, 19), an idea that originated with historian Donald Pisani (Sherow 1990). Thus, water laws and policies have reflected competing priorities and differing values.

The 1891 legislature attempted to divide the state at the 99th West meridian into Eastern riparian and Western prior appropriation rights, but the 1905 Kansas Supreme Court rejected that argument (*Clark v. Allaman, 71 Kan. 206, 80P 571 (1905)*), even though common law water rights made a distinction between surface water and groundwater (Sherow 1990; Peck 1995). As long as environmental conditions are constant, and given the state's climatic differences, droughts, and subsequent water issues including severe southwestern aquifer depletions, the earlier dual water rights system may have been just as useful as a single system.

However, hydrological connectivity has become much more important with regard to streamflow, groundwater, and aquifer thickness, so water laws and a policy system that is more comprehensive can be beneficial.

The 1917 Water Commission was convened to explore state water issues beneficial to the state and its citizens, specifically a shift away from common riparian rights to prior appropriation water rights (Sherow 1990; Peck 1995). In 1944, the Kansas Supreme Court ruled the Commission had failed in a number of ways because the Commission did not recommend amending water laws to reflect changing permitting processes (*State ex rel. Peterson v. Kansas State Board of Agriculture*) (Peck 1995). The common-law rule of absolute ownership remained and the city of Wichita was denied water rights in the Equus Beds (an aquifer) because it was not located over the Equus Beds (Peck 1995). It spurred then-Governor Schoeppel to appoint another committee to examine the state's water laws and recommend changes (Peck 1995). The newer group focused on prioritizing state water rights, especially stream's riparian rights laws beneficial to Reclamation's Kansas water projects and other federal agency projects taking place at the time (Peck 1995, 2014; Griggs 2012; Rogers et al. 2013). Their invited speakers included Spencer L. Baird of Reclamation, Wells A. Hutchins, renowned water lawyer and economist from the U.S. Department of Agriculture, and John Riddell, the Nebraska Assistant Attorney General. Baird and Hutchins in particular were concerned with Kansas's lack of constitutional attention to water rights geographically and quantitatively (Peck 2014). The Committee identified the 1917 Commission's intent and made legislative recommendations based on this and other western states' practices that included:

- an administrative agency to appropriate water and its use,
- water use change over time to focus on irrigation, municipal, and industrial use,
- water should be for beneficial use and thereby appropriated and diverted,
- hydrological connections between surface and groundwater exist, and
- natural resources need consideration (Peck 1995, Griggs 2012).

These recommendations culminated in the KWAA that took less than 10 months to evolve after the Peterson case and the subsequent committee scrutiny of Kansas's water laws (Peck 1995). These ideas and their ramifications have continued for Kansas as they wrestle with past practices, old and new science, growing demands from multiple sectors, legal language, and future environmental water uncertainty.

The KWAA reads, in part, "An Act to conserve, protect, control and regulate the use, development, diversion and appropriation of water for beneficial and public purposes, and to prevent waste and unreasonable use of water" (*1945 Kansas HB 322)*. It further says, "all water within the state of Kansas … to the use of the people of the state, subject to the control and regulation of the state" (*K.S.A. 82a-702*). Implicit is that groundwater and surface water are under the auspices of a single doctrine and the authority of the State Engineer. Current users at the time of KWAA's implementation had vested rights that would supersede new appropriation rights, priority was determined by application date and proof of beneficial use; water use priorities would take precedent, and water was pledged to public use (Peck 1995, 2007, 2014; Griggs 2012, 2017).

Pre-KWAA, surface water generally fell under riparian rights and groundwater was also landowner controlled. The KWAA did not include a process for applying for and receiving an appropriation right, which meant that people would not be legally protected in court over water conflicts. What the KWAA did do was create a system for getting and holding water rights. It enforces a single system for all regions and all water in the state (Peck 1995; Griggs 2012; Rogers et al. 2013).

The KWAA was contested three times before 1963. In 1949, the KWAA was contested over a Kansas Bostwick Irrigation District Number 2 plan for a water impoundment diversion to irrigate downstream riparian and non-riparian lands (*State ex rel. Emery v. Knapp 167 Kan. 546*). Common law prohibited using water on non-riparian land, but the Kansas Supreme Court supported the KWAA because they deemed it beneficial use. Additionally, the Act had not imposed any geographical boundaries, so diverting water to non-riparian land was valid (Peck 1995; Griggs 2012). The Court again upheld the KWAA in 1956 when it was challenged about vested rights and whether or not a landowner had appropriated their water and put it to beneficial use (*Baumann v. Smrha 145 F. Supp. 617 (D. Kan. 1956)*). The Kansas Supreme Court reversed a third challenge to the KWAA in 1962 (*Williams v. city of Wichita 190 Kan. 317*) when a lower court denied the city of Wichita pumping rights in the Equus Beds and pipeline transfer. The ruling asserted that landownership under common law did not automatically confer water rights, although the Chief Justice dissented, saying that an established property right was now defunct (Peck 1995). The KWAA positioned Kansas to address their water challenges in meaningful and reasonable ways by providing directives.

The 1944 U.S. Flood Control Act is nearly concurrent with the KWAA. Under the auspices of Reclamation and the U.S. Army Corps of Engineers, the Flood Control Act supported nine federal Kansas water projects to address flood control and irrigation water supply needs until the 1960s (Peck 1995; Griggs 2012). Bostwick Irrigation District (located in Nebraska and Kansas) uses water dedicated to the Compact and is one of the federal projects. The District is part of Reclamation's Pick-Sloan program, and straddles the Nebraska-Kansas border with two divisions (Griggs 2012). In 1974 after most of the large Reclamation projects were completed, the state enacted the State Water Plan Storage Act to regulate water storage per water rights under the Flood Control Act. Part of the plan created a "water reservation right" that allows Kansas as a water right holder to store water in residence at federal reservoirs and later sell it (Peck 1995). It aligned Kansas's practices in a manner beneficial to receiving federal funding for state projects.

Kansas Litigation and Interstate Compacts

Interstate compacts play a large role in Kansas's water history. They are engaged in four compacts with three states for three interstate rivers: the Arkansas River with Colorado (1949) and Oklahoma (1966), the Republican River with Colorado and Nebraska (1943), and the Big Blue River with Nebraska (1971). As an interstate river, the Missouri River on the state's eastern border has yet to come under any compact with Kansas (Peck 1995; KDA 2016a). Spatially about one-half of the state is part of an interstate compact, as shown in Figure 4.7. Whether upstream or downstream, each can be an unenviable position depending on annual weather trends throughout the larger region, technology, and water practices over time.

People throughout the Arkansas River valley have altered the riparian ecosystem so extensively since the mid-1800s with canals, diversions, and wells, that the river system itself is reduced to a mere economic input with market values that dominate nature (Sherow 1990). The two states would and have remained rivals for the valley's water for over a century.

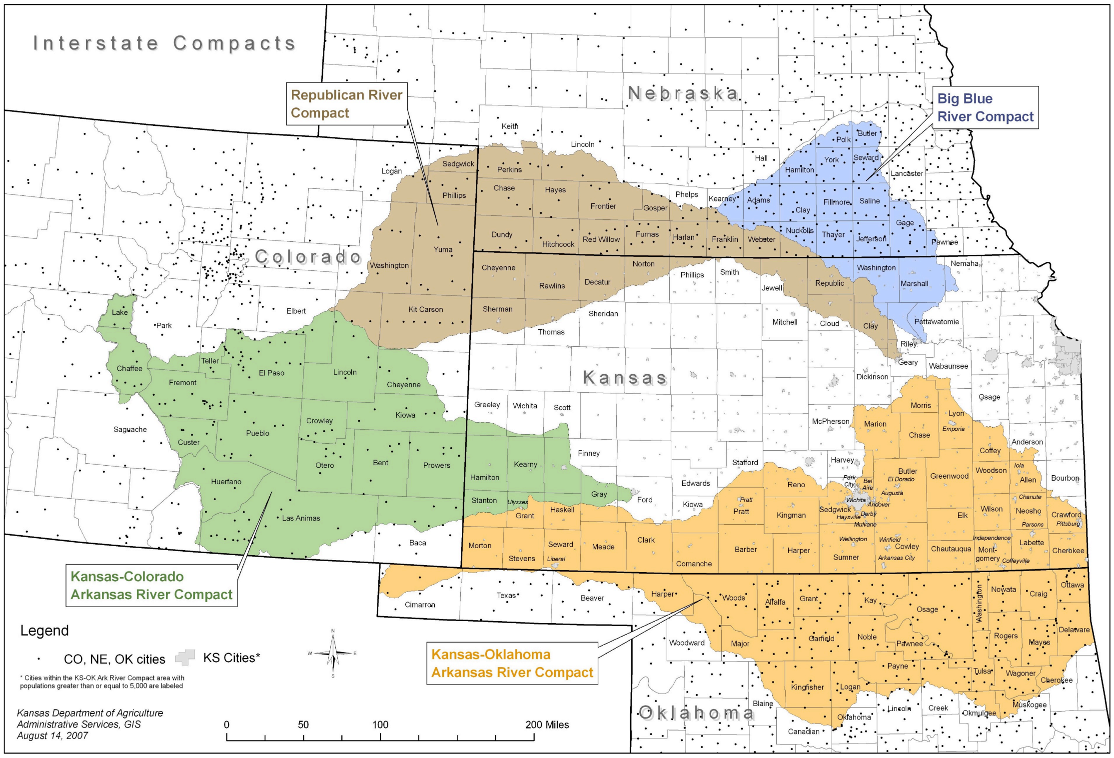


Figure 4.7. Kansas Interstate Compact Agreements. Geographic extent of river basins (KDA 2016a).

Litigation with Colorado over the Arkansas River began in 1902 (Sherow 1990; Peck 1995; U.S. Supreme Court n.d.). The longest running case, *Kansas v. Colorado*, No. 105 Original, took 24 years (1985-2009) to resolve and involved four rulings. The dispute required a Special Master in 1995 for allegations that Colorado had violated the Compact with post-Compact pumping. The 2009 ruling, again by a Special Master, oversaw resolutions to the conflict between the states that included: over-drilling, reduced streamflows, a hydrologic model, monetary damages, and witness fees (*556 U.S.. 98*, 2009). It was estimated that approximately 1,700 wells were capped in Colorado after the first Special Master's report. Further, the Supreme

Court decision was to deny Kansas's monetary claim, a $35 million win for Colorado (Schroeder 2009).

Allocation delivery issues have been a concern on the Republican River, too. Kansas has filed two U.S. Supreme Court lawsuits (*Kansas v. Nebraska and Colorado*, No. 125 Original (1998-2003) and *Kansas v. Nebraska* (2012)). Rulings in both cases were in Kansas's favor. The Compact is discussed in more detail later in the chapter. Kansas's interaction with Oklahoma and Missouri are rather tepid in comparison to the other two compacts.

From 1945-1957 Kansas was able to develop comprehensive water law in less time than other Western states, benefiting from those states' earlier experiences with state water law. It was accomplished by Department of Water Resources (DWR) work, legislative action creating the Water Appropriation Act, Kansas Water Resources Board reports and recommendations, and other legislative amendments. The 1955 Kansas Water Resource Board's mandate was to examine state law with special attention to water resources development. Two well-known Board reports resulted from the work of Robert L. Smith and Earl Schurtz. The 1956 Report analyzed the Kansas Water Act and proposed amendments with an eye towards a state water plan, while the 1960 Report emphasized beneficial water use relevant to current law and groundwater definitions in Western states. Legislative changes, for example, included defining "water right" to include either vested or appropriation rights, water rights as property, and water use status in disputes (Peck 1995, 2004).

Contemporary Water Programs

Kansas has developed several newer concepts to address state water (select programs are listed). Water Banking lets water rights water be placed into a water bank with two use options. Multi-Year Flex Accounts are for groundwater rights holders to deposit and store water over a five-year period for later use during that period. The Irrigation Transfer Assistance Pilot Project Program (ITAP) and the federal Conservation Reserve Enhancement Program (CREP) both retire water rights to help extend the life of the Ogallala Aquifer. Finally, Aquifer Storage and Recovery allows for floodwaters to be diverted and artificially recharge nearby aquifers to be stored for later use (Peck 2014).

Special water districts and areas include drainage, rural water, levees, and groundwater concerns. Groundwater Management Districts (GMDs), Intensive Groundwater Use Control Areas (IGUCAs), and Local Enhanced Management Areas (LEMAs) are agriculturally important because they address water management. GMDs were created in 1972 and have limited local power over issues as long as decisions do not interfere with state policies. Kansas has five regional GMDs, with those in central and western Kansas especially influential in the form of local regulations, standards, policy, and management plans. Their geographical area conforms to the borders of the High Plains-Ogallala Aquifer (Peck 1995, 2007; Rogers et al. 2013; Griggs 2014a). Four sections of the GMD Act were appended in 1978 and led to the creation of IGUCAs in areas where one or more of five conditions are met including significant groundwater declines and preventable waste of water. ICUGAs are identified and controlled by the Chief Engineer. The Chief Engineer can re-assign groundwater withdrawals, deviate from strict prior appropriation, and implement provisions such as closing the area to other water appropriation or require rotating use (Peck 1995, 2004, 2007; Kansas Division of Water Resources 2016b). LEMAs, authored and controlled by GMDs, are an alternative to IGUCAs, and encourage local agricultural producers to plan in concert with their local GMDs to extend the Ogallala Aquifer's useful life expectancy. To date, the first approved LEMA is in GMD 4, Sheridan County in northwest Kansas with a proposal to go district-wide; GMD 5 has proposed a 10-year phase-in program (Kansas Division of Water Resources 2016b).

As water law and policy evolved in Kansas, the DWR's role became more involved and complex, especially as the number of available water rights became more limited and demand for water expanded. It was especially true as the 1980s began and water holdings required more enforcement. The Kansas legislature connected surface water and groundwater as a single hydrologically interconnected system with the KWAA and its amendments, as well as creating a central administration with the DWR. Kansas responses may be considered more nimble to changing water circumstances than Nebraska where control is split between the DNR (surface water) and the NRDs (groundwater). Most recently Kansas has developed and is implementing a statewide water plan that addresses its contemporary challenges including reservoir infilling and aquifer depletions, plus presenting various solutions (Kansas Division of Water Resources 2015).

NEBRASKA

Nebraska adopts a quite different approach to water law and policy than do Colorado and Kansas where prior appropriation is followed. Nebraska utilizes prior appropriation with its surface water, but a hybrid reasonable use and correlative rights doctrine for ground water (Blankenau, Wilmoth, and Bromm 2005; Aiken 2006; Griggs 2017). In 1895, the state adopted prior appropriation for surface water; earlier the state used traditional riparian rights doctrine, and groundwater was defined in 1933 (*Olson v. City of Wahoo*) (Blankenau[3], Wilmoth, and Bromm 2005). Jurisdiction is also decentralized compared to the other states. Surface water is regulated by the Department of Natural Resources (NDNR) (formerly the Department of Water Resources), while groundwater is regulated by local Natural Resource Districts (NRDs) (Aiken 1980; Bleed and Hoffman Babbitt 2015; Griggs 2017; NDNR n.d.). The NDNR director, equivalent to the chief engineers in Kansas and Colorado, oversees most state surface water issues for the entire state, while NRDs are charged with overseeing groundwater within their geographic borders. Both deal with permits, adopt and enforce rules, and maintain plans among other duties.

The remainder of the Nebraska section is divided into surface water, groundwater, and integration. It follows a largely chronological presentation. Irrigation priorities, resource agencies, NRDs, and legislative and legal actions that ushered in integrated management plans (IMPs) are included.

NEBRASKA SURFACE WATER

Nebraska is a topographically gentle, undulating plain with few highs and lows, resulting in streams and rivers with low gradients, whose flows are subject to

[3] Don Blankenau served as the former General Counsel, Assistant Director, and Interim Director at the Nebraska DNR between 1991-1999.

the whims of weather in the south and west, as compared to those in the north, central and east that are groundwater fed (Bleed 1993; Manley 1993; Bleed and Hoffmann Babbitt 2015). Like Kansas its southern neighbor, Nebraska's climate and precipitation regime is similar with a wet east and drier west (Bleed 1993; Bleed and Hoffman Babbitt 2015). Eastern settlers were not used to the treeless plains, semi-arid and arid conditions, and lack of streams (Mossman 1996; Manley 1993; Gless and Longo 2008). Transforming Nebraska into a water-rich environment was a challenge just as it was for Kansas and parts of Colorado.

Three possibilities presented themselves. Robert Furnas, the state's second governor, believed irrigation was the best alternative. Samuel Aughey believed that precipitation was positively correlated with the expansion of westward movement and along with J.T. Allen proposed tree planting to increase precipitation (Manley 1993; Gless and Longo 2008). An 1879 U.S. Congressional proposal to restrict settlement west of the 100th meridian was suggested to maximize available water; John Wesley Powell supported it and believed settlement would not be agriculturally amenable without extensive supplemental water (Stegner 1982; Manley 1993). Eventually settlers had no choice but to find viable alternatives to tree planting and the westward migration of increased precipitation. It would be irrigation that led to state water laws and policies.

It began with ditches and canals. The first water law came with the 1877 legislature's acknowledgement of irrigation districts as improvements, and in 1914 vested surface water rights were added (Gless and Longo 2008). W.R. Akers and C.W. Ford discovered Nebraska had no water rights laws while excavating for their canal near North Platte. They sent a copy of Colorado's water laws to the state legislature and became the first to register water rights in 1888 (Manley 1993; Mossman 1996).

In 1880, Guy C. Barton of North Platte, complained to Governor Nance about low flows in the South Platte coming from Colorado. By 1887 South Platte complaints had increased, emboldening John Wilson to correspond with Governor Thayer documenting Colorado's over-use. Colorado's Attorney General responded with sympathy to Nebraska's concern, but Colorado had prior appropriation laws within its state, and there was nothing he could legally do about the lack of water for Nebraska (Manley 1993). Water's transitory qualities and inability to be bound by space are evident (Jones and Macdonald 2007). These actions and documents foreshadow later transboundary water conflicts between the two states and subsequent compacts and agreements such as the 1923 South Platte River Compact[4]. Spurred on by a proposed dam on the South Platte in Colorado, the first irrigation law passed in 1889, the St. Rayner Law. It required water users to post a sign, use water beneficially, and begin within 60 days, as well as streamflow apportionment during shortages. It did not address priority or usage preferences (Manley 1993; Mossman 1996; Gless and Longo 2008).

The early 1890s saw similar pushes for irrigation and federal support for projects in light of drought and the state's downstream location on the Platte (Manley 1993; Gless and Longo 2008). The 1895 Appropriation and Irrigation Code, Aker's Law identified prior appropriation and beneficial use among other features for surface water. It allowed citizens the right to create irrigation districts, levy taxes,

[4] Future agreements include the 1997 Platte River Cooperative Agreement between Colorado, Wyoming, and Nebraska and the 2001 North Platte River Settlement with Wyoming.

and issue bonds, but diversions were not an absolute right (Manley 1993; Schafer 1993; Mossman 1996; Gless and Longo 2008). O.V.R. Stout and Erwin Hinckley Barbour advocated for a comprehensive state water assessment. Barbour also addressed the need for proper agricultural techniques focused on soil moisture conservation and finite water resources. He and others warned that surface water supplies would not be the panacea of the semi-arid and arid West Platte River and Republican River estimates were too ambitious; the Platte could be over-allocated; dams and reservoirs would be necessities (Bleed 1993; Manley 1993).

Nebraska identifies four types of prior appropriation surface water rights: natural flow, storage, storage use and instream flow. Five beneficial uses are connected to natural flow — domestic, agriculture, irrigation, manufacturing, and power generation. Natural flow is water diverted off a surface body (a river or a lake) and to a canal, for example, and instream flow refers to the water actually flowing in a stream. Storage rights allow for impounding water, but not its use, and include underground storage and recovery. Storage use rights are for the actual use of stored water (Blankenau 2009). Incidental underground water storage that occurs due to irrigation canal seepage is also covered (Blankenau 2009).

The NDNR is tasked with supervising and controlling surface water appropriations, diversions, and distribution of public water. A prior appropriation right is a right of use *only* and must have a beneficial and useful purpose; it is true for Colorado and Kansas as well. Surface water rights/permits[5] include the presence of unappropriated water, the amount of water diverted, the maximum amount of

[5] The Nebraska DNR website uses 'surface water right/permit' and makes no distinction between a right and a permit.

water for beneficial use and purpose of use (such as irrigation), the location of use and the diversion works, and the priority date. Junior rights holders defer to senior rights holders (Blankenau 2009; NDNR n.d.a.). Interestingly, the NDNR does not need to consider how surface flows may be hindered by later groundwater development when surface water permits are issued. Thus, surface water users could potentially be adversely affected by later groundwater development that decreases surface water flows and quantities due to hydrological connectivity. In turn, that sets in motion plausible conflicts between surface and groundwater users. Adjudication of appropriation rights is overseen by the NDNR as well. Rights are evaluated based on reasonable and continuous use but can be cancelled by forfeit, non-use, abandonment, and prescription. Challenges are made directly to the NDNR who can hold a hearing, and challengers can appeal a NDNR ruling (Blankenau 2009).

Nebraska Groundwater

Aiken (1980) describes how groundwater wells changed agriculture, irrigation and the subsequent need for law and policy (Table 4.1). From the 1930s to the end of the 1970s, the number of wells swelled from 1,900 to over 63,000. Total irrigated acreage in Nebraska increased from 500,000 to 3.2 million. Groundwater acres outnumbered surface water by a ratio of 3:1. The 1930s Depression and Dust Bowl, a drought from 1952-1956, the advent of the turbine pump that allowed for deeper wells and easier extraction, sprinkler irrigation systems, and center pivot irrigation systems designed to operate on slopes all contributed to groundwater expansion. In 1975, groundwater irrigation pushed Nebraska to a national number three ranking for irrigated acres and groundwater withdrawals. Legislation was necessary and inevitable, given the rate of groundwater use expansion. A withdrawn 1940 bill (LB 460) that considered a statewide groundwater system with a combination of overlying rights and appropriation could have addressed groundwater issues, but instead it was delayed. 1957 and 1958 saw legislative action on well registration, spacing, and water use preferences. However, details such as enforcement and definitions were not included. 1963 groundwater statutes included a permit system, but did not include sub-flows, as recommended by a 1962 report (Gless and Longo 2008). That lack "contributed to retarding development of integrated ground and surface water management in Nebraska by thirty to forty years" (Gless and Longo 2008, 104).

Five hundred resource-related entities with murky jurisdictions and authorities over water existed in Nebraska by the 1960s. The 1967 Interstate Groundwater Transfer Act allowed water transfers and uses between states by property owners as long as the neighboring state had a reciprocity clause, so water could be from Nebraska and used in Kansas. A 1982 challenge to the statute led to the U.S. Supreme Court, *State ex rel. Douglas v. Sporhase*, where the Court identified water as an article of commerce. Nebraska severed the reciprocity clause, and Sporhase and partner obtained a water use permit (Schafer 1993; Gless and Longo 2008). Just as important was the Nebraska Supreme Court's recognition in the *Little Blue NRD v. Lower Platte NRD* (1982) that surface water could be transferred to recharge mined groundwater areas (Gless and Long 2008).

Table 4.1. Nebraska Irrigation Wells and Irrigated Acreage, Select Data.

1860	9,000 irrigated surface water acres
1890	12,000 irrigated surface water acres
1900	150,000 irrigated surface water acres 1,000 irrigated groundwater acres
1920	450,00 irrigated surface water acres 1,000 irrigated groundwater acres
1930s	1,900 total ground water wells 1,000 in 1935
1940s	4,000+ groundwater wells 330,000 added groundwater irrigated acres 500,000 total surface and groundwater irrigated acres
1950s	16,000 groundwater wells 2 million total surface and groundwater irrigated acres groundwater acres outnumber surface water acres
1960s	Center pivot irrigation systems take hold 3:1 groundwater acres outnumber surface water acres irrigated groundwater acres increase from 1.4 million to 3.5 million
1970s	29,000 groundwater wells (63,000 cumulative total) groundwater acres double 1979 ~85% of state groundwater irrigated 1970-1979 irrigated acres went from ~4 million to ~7 million
1980s	6.2 million groundwater irrigated acres, ~1 million surface water acres
1990	7 million groundwater irrigated acres, surface acres stable
2000	~8.1 million total irrigated acres
2010	~8.6 million total irrigated acres

(Aiken 1980; Dreeszen 1993; Nebraska Energy Office n.d.)

Groundwater law came last. Groundwater is defined as "that water which occurs in or moves, seeps, filters, or percolates through ground under the surface of the land" (*Neb. Rev. Stat. 46-7-6 (2)*). Groundwater rights are property rights, are attached to overlying land, and cannot be transferred (Aiken 1980; Mossman 1996; Peck 2007); some groundwater right transfers were later made possible (Blankenau, Wilmoth, and Bromm 2005). In 1933 Nebraska's Supreme Court adopted the American rule or reasonable use rule — landowners must use water beneficially, resist over extraction, and do no neighborly harm — with a stipulation. If underground water is insufficient during shortages, it is apportioned between users; these are known as correlative rights in Nebraska (Mossman 1996; Gless and Longo 2008; Bleed and Hoffman Babbitt 2015). Nebraska therefore has co-mingled the reasonable use doctrine with correlative rights resulting in the Nebraska rule of reasonable use. Other rules addressed ownership and conflict, but ignored or avoided hydrologically connected systems, at least until the 1966 Omaha Metropolitan Utility District (MUD) case. The Nebraska Supreme Court allowed MUD to attain surface water rights on the Platte River to protect nearby groundwater wells, dismissing objections about negative impacts and riparian owner rights concerns (Aiken 1980; Mossman 1996; Popelka 2004; Gless and Longo 2008).

Shortly thereafter, Natural Resource Districts (NRDs) were created in 1969 to manage local resources including groundwater. They have the power to tax, to declare eminent domain, and have broad regulatory authority to allocate water, assure use, enforce non-compliance, and create groundwater control areas (Aiken 1980; Blankenau 2010; Peck 2007; Gless and Longo 2008; Bleed and Hoffman Babbitt 2015). Under the statutory framework of the Groundwater Management and Protection Act (*Neb. Rev. Stat. 46-701 to 753*), groundwater quantity is first under the jurisdiction of the local NRDs, but requires NDNR approval for management plans, and the Department of Environmental Quality oversees water quality (Aiken 1980; Blankenau 2010; Bleed and Hoffman Babbitt 2015). NRDs can designate all or a portion of its district as management areas and issue cease and desist orders. They have extra authority to regulate quantity and quality, allocate withdrawal amounts, institute rotating use systems, well spacing restrictions, require well meters and other methods to ensure best practices, and a sustainable access (Aiken 1980; Gaul 1993; Bleed and Hoffman Babbitt 2015). NRDs are largely independent of centralized state oversight except for those exceptions such as integrated groundwater management plans.

INTEGRATION OF SURFACE AND GROUNDWATER

Until 1996, Nebraska had avoided incorporating ground and surface water laws, instead preferring to keep them separate, in contrast to Kansas (1945) and Colorado (1876 and 1882) (Peck 1995; Mossman 1996; Popelka 2004). Nebraska began the laborious process of merging and reconciling the laws and statues with 2005's LB 108, Integrated Water Management. It was undertaken in light of looming threatened legal action by Kansas alleging over-use by water users in the Republican River basin in violation of the Compact. Integrated Management Plans (IMPs) are the responsibility of NRDs who need approval from the NDNR's director (Peck 2007). Jurisdiction can be seen as jointly held between the two agencies, but NRDs have veto power over proposed IMPs. IMPs are a planning mechanism to address water management and are *not* regulatory measures. Additionally, a late 1980s drought had decimated the western Sand Hills region of the state along with depleting groundwater levels (Gless and Longo 2008). Despite the Nebraska legislative efforts, Kansas filed suit with the U.S. Supreme Court in 1998, *Kansas v. Nebraska and Colorado*, No. 125 the Original (Popelka 2004); resolution occurred in 2002 with the Final Settlement Stipulation (FSS) and development of a groundwater model (Blankenau 2010; Schlager et al. 2012; Griggs 2017; RRCA n.d.a., n.d.c.). Groundwater continues to be managed by the NRDs and surface water by the NDNR.

A 2002 Water Policy Task Force (Legislative Bill 1003) was commissioned to investigate integrated water management and make policy recommendations including surface and groundwater inequities and how to address them (UNL Water 2017; NDNR n.d.). The legislative result of the task force's recommendation is Nebraska's Groundwater Management and Protection Act or LB 962 (*Neb. Rev. Stat 46, 7* (2004)) and is "perhaps the most significant water policy legislation ever passed by the Nebraska legislature" according to Don Blankenau, former legal counsel, assistant and interim director for the Nebraska Department of Water Resources (now DNR) (Blankenau 2009). With their political clout and numbers, groundwater users and promoters were able to ascertain protections in their favor, while surface water users have fewer protections, but more than previously provided (Bleed and Hoffman Babbitt 2015). It established cooperative efforts between NRDs and the NDNR to further develop water management plans. Those plans are designed to promote economic prosperity, including the agriculture sector, for hydrologically connected surface and groundwater areas that is equitable and optimizes beneficial use; these hydrological relationships need unique management strategies (Ostdiek 2009; Bleed and Hoffman Babbitt 2015). One task given to the DNR is to conduct annual evaluations for basins previously undesignated as fully- or over-appropriate; these designations refer to the number of wells and available water. Nebraska already has nearly 50% of its river basins designated as fully or over-appropriated; it includes all or part of 11 NRDs as designated by the NDNR

(Ostdiek 2009; Bleed and Hoffman Babbitt 2015; Figure 4.8). The NDNR can issue stays for new surface or groundwater uses in fully- or over-appropriated basins, who are required to have Integrated Management Plans (IMPs) developed by the NDNR and NRDs. Affected basins are the Platte River and its three segments, South, North and main, the Republican River, the White River, the Hat Creek River, and the Niobrara River (Ostdiek 2009; Bleed and Hoffman Babbitt 2015).

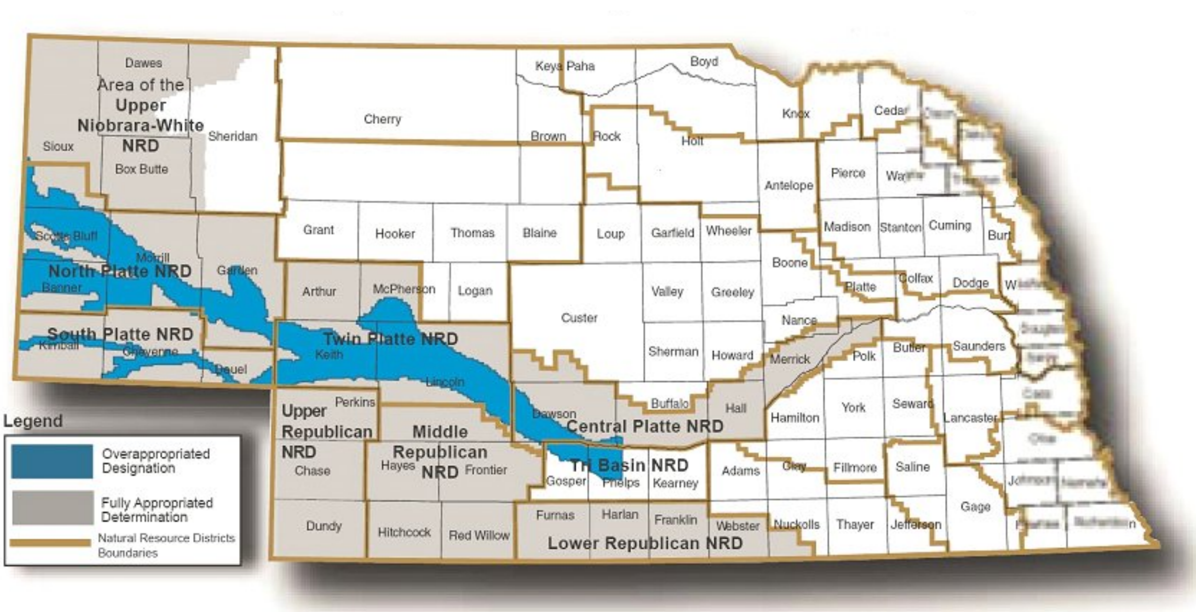


Figure 4.8. Nebraska Fully- and Over-Appropriated River Basins (South Platte Natural Resource District. n.d.).

The most notable legal challenge to LB 962 was the *Spear T Ranch v. Knaub* (*691 N.W. 2d 116*, 2005). A surface water user (Spear T Ranch) alleged that a neighboring groundwater user (Knaub) had dewatered Pumpkin Creek and the surface water user's right was impaired as a result. Spear T sought an injunction to prevent further pumping and $4,000,000 in damages because Knaub had injured their economic livelihood (Blankenau, Wilmoth, and Bromm 2005; Aiken 2006). The district court's decision that the district court had no jurisdiction and that Spear

T should have done more legally was appealed to the Nebraska Supreme Court. The Nebraska Attorney General and the Nebraska State Irrigation Association were two of five parties who filed amicus (friend of the court) briefs (Blankenau, Wilmoth, and Bromm 2005; Aiken 2006). The Supreme Court declined to apply surface water appropriation rules to the conflict and suggested that it was a conflict best resolved by the Nebraska legislature (Blankenau, Wilmoth, and Bromm 2005; Aiken 2006). However, the Court put *hydrologically* connected groundwater into the riparian system; in other words, hydrologically connected groundwater essentially became riparian water. It put groundwater well owners and municipalities at risk for liability even when they were lawfully using groundwater (Blankenau, Wilmoth, and Bromm 2005; Aiken 2006). As J. David Aiken so clearly states,

> If groundwater users are not financially liable for the harm resulting from a dried-up stream, the message is that protecting streamflows has no value, a message that could well doom future administrative efforts to protect Nebraska streamflows. Payment…would support the political case that protecting streamflows now…is a better policy than waiting for the streams to go dry.
>
> Nebraska has finally recognized in both its statutes and in its water jurisprudence that surface and ground water are hydrologically connected. However, just as streamflow depletion from tributary ground water pumping has taken decades to become manifest, there will likely be decades of trial and error iteration before our HC [hydrologically connected] water policies become comprehensive (2006, 996).

Recent legislative action that addresses Nebraska water challenges includes 2014's LB 1098, the Water Sustainability Fund *(Nebraska Revised Statute 46-755)*. It has three elements. One, for basins with required IMPs and three or more NRDs, a basin-wide management plan must be designed. Two, it created a Water Sustainability Fund to meet statewide sustainability goals, and three, it expanded the state's Natural Resources Commission. The basin-wide plans incorporate three water goals: sustainability, compliance, and a 30-year deadline. The Republican River basin is the only state basin that must develop a plan and overlap with IMPs in the basin is expected (NDNR 2017; Nebraska Natural Resources Commission n.d.). The bill is an attempt at funding water management plan development and reconciling the needs of surface and groundwater users at the basin level within NDNR and NRD legislative directives. NDNR has held on going meetings for the Republican River Basin-wide Management Plan since March 2015 and hopes to complete the plan by late 2017 or early 2018 (NDNR 2017).

Legislative action since the 1990s has clarified Nebraska water policy with NRDs by recognizing hydrological connections and requiring annual basin evaluations for well appropriation density (Mossman 1996; Peck 2007; Gless and Longo 2008), but issues remain. For example, NRDs determine a basin's water status as under-, fully- or over-appropriated, and it benefits them to designate basins as fully- rather than over-appropriated, avoiding the annoying hydrological connection complications. In simple terms an under-, fully-, and over-appropriated basin refers to surface water and hydrologically connected groundwater and the quantity of available water in the present and into the future. Fully-appropriated implies that those water supplies are equal to but not beyond the amount of water available over the long-term. Over-appropriated means that demand exceeds supply, and both surface flows and groundwater table levels will decline to such an extent that water will become unavailable or be too expensive to access (Ostdiek 2009). *Nebraska's Rev. Stat. 46-713(3)* and *(4)(a)* sets out very specific criteria for basin identification including whether or not it is subject to an interstate cooperative agreement. Over-appropriation explicitly states that the interstate cooperative agreement has to be between three or more states. The only basin in Nebraska that meets the criteria is the Republican River with the 1943 Compact. Having such a designation can trigger closures in the basin and suspend drilling new wells (NDNR 2005). To date, the Republican River basin has been designated as a fully-appropriated basin.

Furthermore, surface water remains under prior appropriation rights and groundwater has correlative rights through the Groundwater Management Protection Act (Mossman 1996). Gless and Longo (2008) observe that “litigation in Nebraska has been and continues to be a major method of water policy making“(92) and that the court will continue to play an important role in water law and policy especially without legislative guidance.

Water as a physical entity respects its own boundaries, but people can shift those boundaries under political and social demands with diversions, reservoirs, and usage allocations in space and in time. Jeff (Gordon) Fassett, current Director of the NDNR, acknowledges that border areas are becoming more important, particularly where two political borders meet but their physical and policy realities differ (NSIA/NWMA 2016). Interstate water compacts are one means for states that share a river basin and its waters to accommodate their mutual interests. The next section describes the development of interstate compacts and the Republican River Compact relative to the challenges the states face under the agreement.

Water Law and the Republican River Compact

Interstate Compacts

Interstate compacts owe their origin to Delph Carpenter, a Colorado water lawyer who saw an opportunity to solve water conflicts between states that did not rely on federal litigation (Tyler 2003). As a native Coloradoan who was raised on an irrigated farm in northeastern Colorado's Weld County near Greeley, he brought his intellect and personal experiences to bear on solving interstate water problems in a manner that recognized the need for comity over priority or competition (Tyler 2003; Rettig 2017a). By applying comity for states in an interstate agreement, it meant that each state was internally independent from the others, respected the other states' internal decisions, and at the same time adhered to the agreed upon compact regulations and rules. Thus, state's rights were largely protected from compact interference and the other states.

Two early interstate lawsuits alerted Carpenter to explore alternatives to trial court cases: *Kansas v. Colorado* for the Arkansas River (1907), and *Wyoming v. Colorado* for the Laramie River (1911-1912). These cases exposed Colorado's vulnerability to downstream states' claims to upstream water that had its origins in Colorado (Sherow 1990; Tyler 2003), and in general downstream exposure to upstream overuse. In the *Kansas v. Colorado* case, Carpenter had concluded that Colorado was eventually going to have to supply water to Kansas (Tyler 2003). In the case of *Wyoming v. Colorado*, Carpenter was the legal counsel for the Greeley-Poudre Irrigation District. It was constructing a tunnel to transfer water from the Laramie River and basin to the Cache la Poudre River and basin for irrigation use. With the filing by Wyoming and their claim to the Laramie River water, Colorado appointed him as lead defense counsel; he argued this case twice (1916 and 1918) before the U.S. Supreme Court (Tyler 2003). His initial view that Colorado was entitled to all the Laramie River water underwent a transformation to an equitable share position. During this period, and along with a suit from Nebraska on the South Platte River, it became clear to him and others that Colorado would need to address interstate water issues, and that interstate compacts would be more effective than litigation (Tyler 2003).

Carpenter took the U.S. Constitution's compact clause (Article I, section 10 that refers to agreements made between states) and applied it to interstate water conflicts (Tyler 2003), meaning congressional approval for such an agreement would be necessary. He proposed it in 1920 at a League of the Southwest conference that was focused on the Colorado River (Tyler 2003; Rettig 2017b). As a result of his ingenuity and desire to protect western states' control of western water rather than federal control from the Department of Interior or the Bureau of Reclamation, Colorado became party to nine interstate compacts. Carpenter was instrumental in seven, the most significant the 1922 Colorado River Compact (Tyler 2003; Rettig 2017a). Other states would follow Colorado's lead.

Another important case that influenced Carpenter and interstate compacts is the *Hinderlider v. La Plata River and Cherry Creek Ditch Co.* (U.S. Supreme Court 1938). The Supreme Court ruled that the apportionment is binding to each state's citizens regardless of earlier granted state water rights. Other pertinent holdings established in earlier cases include the waters of an interstate stream must be equitably apportioned between states, upstream states cannot divert or control all the water to the detriment of downstream states, states cannot internally authorize more water than its share, water use can be rotated between the states dependent on conditions, and that the Court retains the jurisdiction to determine the validity and effect of the compact (Peck 1995; Griggs 2017; Justia 2017).

Additionally, Western water compacts were often negotiated with limited streamflow data and an assumed long-term stable streamflow that would accommodate use (Schlager et al. 2012). That assumption has critical ramifications for surface flows as groundwater pumping has increased, for understanding historical and contemporary hydrological connections, changing environmental conditions such as increasing temperatures impacting evaporation rates, shifting and increasing populations with their accompanying water demands, and peoples' changing water perspectives. These issues are ones that socio-hydrologists, geographers, water managers, and legislators are working to address (Michaels and Kenney 2000; Barnett et al. 2008; Sugg et al. 2016; Welsh and Endter-Wada 2017a). Market-culture values shift as perceptions of water and nature shift.

REPUBLICAN RIVER COMPACT

The 1943 Republican River Compact is part of Delph Carpenter's legacy in the tri-basin states. Its eleven articles address among other items efficient use, equitable division, comity, beneficial use, flood protection, the river's virgin water, state allocations, and reservoir and diversion construction. The basin itself presents physical challenges, since droughts are frequent and surface water is scarce due to unpredictable annual and seasonable precipitation

Encouraged by various federal initiatives like the 1841 Pre-Emption Act, the 1862 Homestead Act, the 1873 Timber Act, the 1877 Desert Land Act (only

Colorado), and the 1902 Newlands Reclamation Act people migrated to and settled in the larger region and the Republican River basin. Their economic base was primarily agriculture, dry land farming, and ranching. If they had access to surface water, some were able to divert water and irrigate small portions of their claim or form mutual irrigation ditch companies (Manley 1993; Griggs 2012). A few were able to use windmills and pump easily accessible groundwater (Manley 1993; Schafer 1993). Successful operations encouraged others to find their way to the remote Republican River valley, and eventually small communities found a foothold. Of these Acts, perhaps the most important to residents of the valley is the 1902 Newlands Reclamation Act. With its promise of irrigation water projects from the funding of semi-arid federal land sales, Western residents would be able to have reliable water (Griggs 2012), at least theoretically.

The 1930s saw a nearly decade-long drought in the Great Plains. In the Republican valley, it was compounded by a deadly 1935 flashflood that claimed at least 100 lives. These two events, the region's ongoing need for agricultural water, local leaders' demands for help, and the Reclamation's vision of a comprehensive basin plan in an undeveloped location led them to propose a solution. Reclamation would assist with flood protection by capturing high flows in nine dams and reservoirs and then deliver those excesses via irrigation canals to irrigation districts for their use (Manley 1993; Blankenau 2010; Griggs 2012, 2017; RRCA n.d.a.). However, in order to receive the benefits of federal assistance, Reclamation required the states to participate in an interstate compact to allocate the Republican River's water and reduce potential litigation among them (Griggs 2017). An earlier 1929 interstate compact attempt was unsuccessful when Kansas declined to participate

(Blankenau 2010), but the latter 1943 attempt was successful and the Compact became law.

Virgin water supplies were divided among the states and defined as “the water supply within the Basin undepleted by the activities of man” (Republican River Compact). The annual virgin water supply equaled all the gaged flows of the river and its tributaries plus the flow amount not impacted by human activity (Blankenau 2010), for example, water provided from a source outside the river basin that could augment flows. The basin’s water was divided as follows: Colorado receives 11%, Nebraska receives 49%, and Kansas receives 11% for its upstream portion and 29% for its downstream portion to total 40% (Blankenau 2010, Republican River Compact). “Virgin water” was defined as “the waters of the basin undepleted by the activities of man.” As written at the time, hydrological connections were less well understood, but with the advent of submersible pumps, center pivot irrigation, and better hydrologic science, conflicts became inevitable between surface and groundwater users and the states, lately requiring augmentation projects due to Nebraska overuse (Blankenau 2010; Griggs 2017; Figure 4.9).

In 1961, the Republican River Compact Commission (later the Compact Administration or RRCA) met to develop policies and procedures for water calculations, implementations, and state adoptions; a full 17 years after ratification. Kansas requested that groundwater well pumping impacts be part of the calculations, but was rebuffed; alluvial wells near the river were already included (Blankenau 2010; Griggs 2012). Irrigation usage continued to increase over the next few decades, especially with Nebraska groundwater wells; declining streamflow became a concern for Kansas. Kansas again requested the RRCA to include non-alluvial well impacts as part of RRCAs accounting rules and procedures to which Nebraska objected (Blankenau 2010; Griggs 2017; RRCA n.d.a.; Figure 4.10).

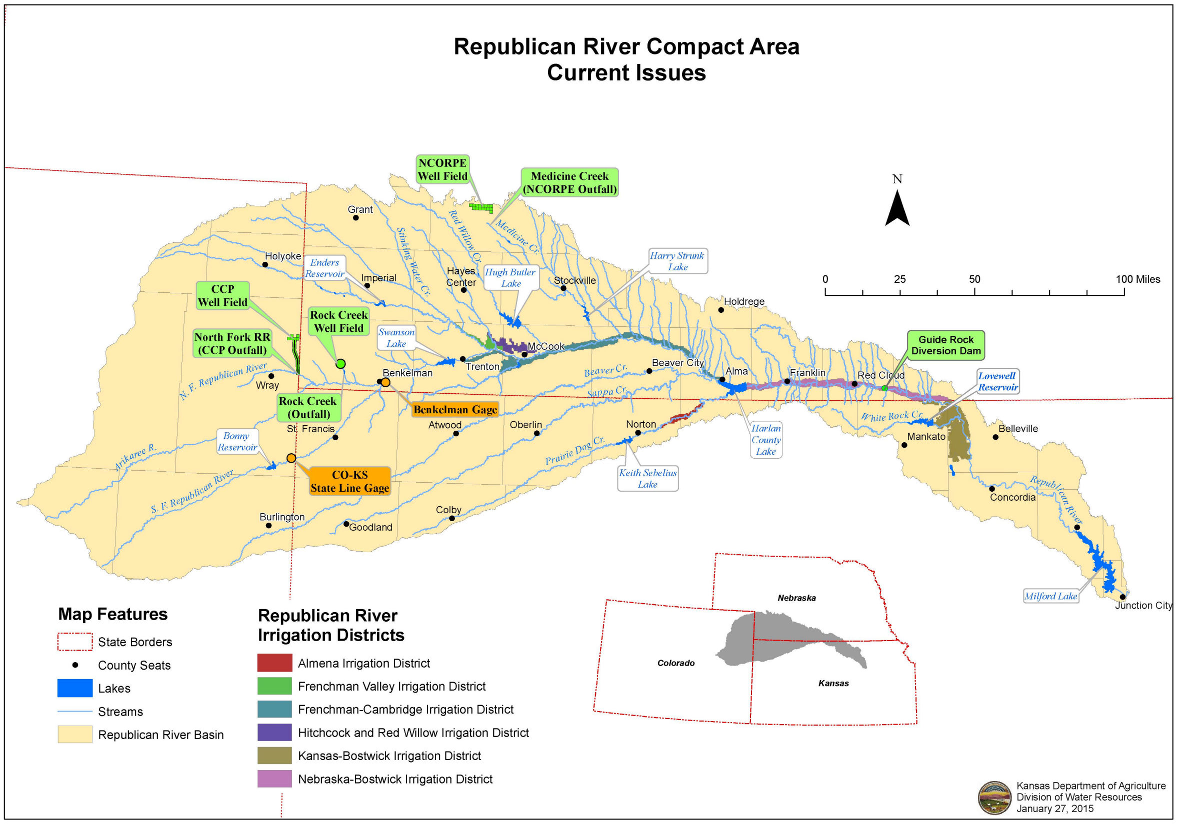


Figure 4.9. Colorado and Nebraska Compact Augmentation Projects: Colorado Compact Pipeline (CCP), Rock Creek, and N-CORPE (KDA n.d.).

Without resolution between the two states for adopting non-alluvial well procedures, Kansas filed a U.S. Supreme Court complaint in 1998 against Nebraska and Colorado, *Kansas v. Nebraska and Colorado*, No. 125, the Original (Blankenau 2010; Griggs 2012, 2017). In the case of interstate water compacts, disputes between states falls under U.S. Supreme Court jurisdiction. Kansas sought to compel the adoption for non-alluvial wells i.e., groundwater wells, and Nebraska filed a petition to dismiss Kansas's suit. In response, the U.S. Supreme Court assigned a Special Master who oversaw various reports, exceptions, amendments, and mediations eventually culminating in the 2002 FSS that incorporates groundwater into the Compact (Blankenau 2010; Griggs 2012, 2017).

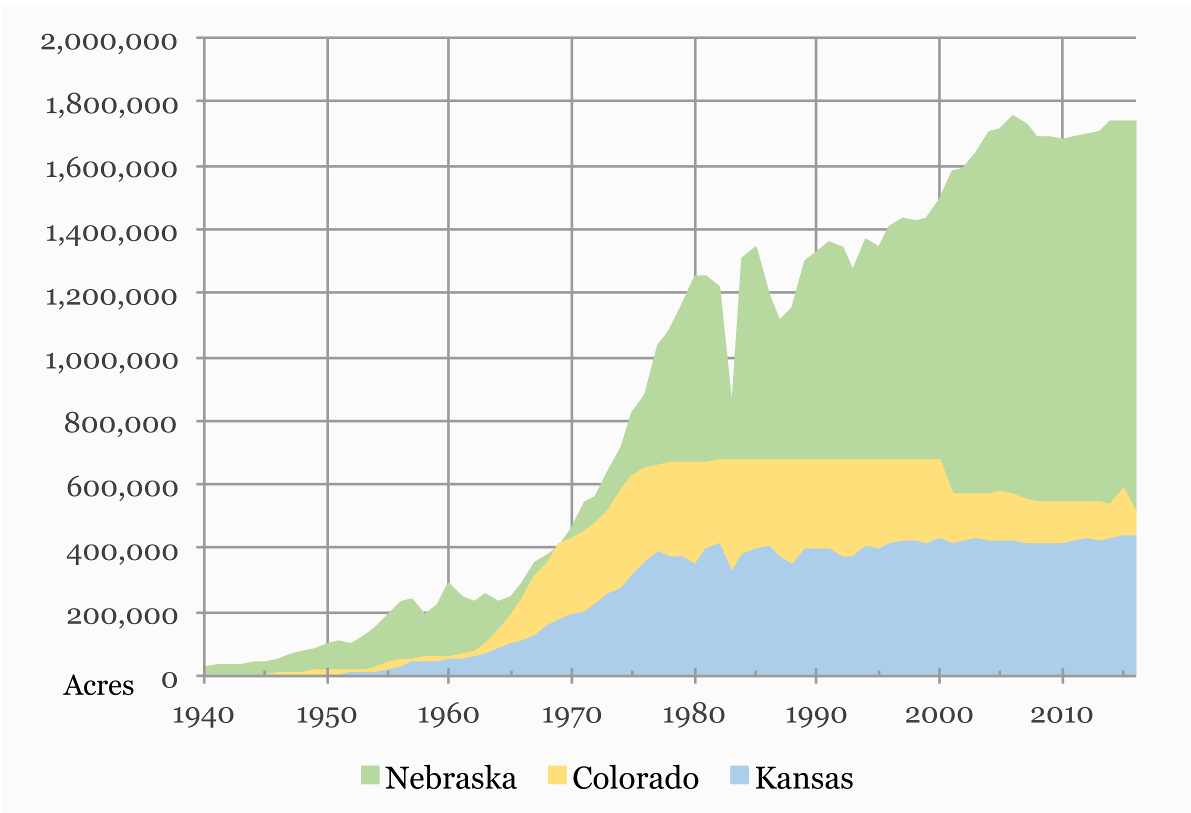


Figure 4.10. Republican River Basin Groundwater Irrigated Acres, 1940-2016 (RRCA n.d.c.; Author).

The FSS is a 5-volume report with two primary features: one, the joint development of a basin wide numeric groundwater model, and two, using a multi-year average methodology (Blankenau 2010; Griggs 2017). The groundwater model includes hydrological connections and calculating streamflow depletions from groundwater (Blankenau 2010; Griggs 2017). A running mean or multi-year average to determine allocations means that low or high precipitation years can more readily be accommodated. Theoretically, previous years' water profiles inform future water predictions and offer an opportunity to construct regulations that ensure compliance (Blankenau 2010).

Of the three states, Nebraska was the only one who did not already have groundwater monitoring procedures in place (Schlager et al. 2012; Griggs 2017). Colorado's response was to create the Republican River Water Conservation District to meet its Compact duties. Colorado is committed to retiring surface water wells and using a groundwater augmentation pipeline (Jones and Cech 2009; RRWCD 2009; Deb Daniels, manager RRWCD, pers. comm. 2016; Griggs 2017; Figure 4.11).

Figure 4.11. Republican River Water Conservation District groundwater augmentation pipeline, Colorado (RRCWD 2009).

Because the river's streamflow volumes are unpredictable, presently states make predictions based on forecasts that include past use and predicted future needs. As an example, see the NDNR's *Forecast of Allowable Depletions in the*

Republican Basin documents on their website. Based on the forecast, Nebraska as an upstream state determines how much water will be available for use and how much needs to be sent downstream to meet the commitment to Kansas. Once the irrigation season is over, the states use FSS procedures to determine the "actual" amount of virgin water that was available and whether or not each state stayed within their allocation (NDNR 2016).

The states agreed that the actual groundwater model use would begin with 2006, giving them time to develop and coordinate a complicated hydrological model. Concerns arose by 2005 over possible accounting inaccuracies in the model, accurate hydrologic connections, and Nebraska over-use (Blankenau 2010; Griggs 2017). In 2005 and 2006, Nebraska overused 35,000 AFY each year (Griggs 2017). Kansas agreed with Nebraska that inaccuracies existed, but did not agree to rule modifications. That meant the 2006 calculations could not be certified or approved by the RRCA (Blankenau 2010; Griggs 2017); they were not certified until 2015 (RRCA n.d.c.).

The two states continued to be at odds, each seeking resolution with non-binding arbitration. A 2009 arbitrator's 73-page decision basically rejected Kansas's demands to reduce the number of groundwater wells, did not endorse a river master, and limited their damages to $10,000. The arbitrator advised Nebraska to institute better regulation in light of future drought conditions and agreed that the calculation should change, but rejected Nebraska's proposal regarding model inaccuracies (Blankenau 2010; Griggs 2017). The decision did not take into consideration over-use during non-drought conditions (Griggs 2017).

Nebraska did undertake efforts to lessen groundwater pumping impacts by modifying its Integrated Management Plans with the NRDs and NDNR (Blankenau 2010; Griggs 2017). Nebraska's 1996 LB 108 had required the Republican River basin's four NRDs to take a basin-wide approach, since the basin was under the greatest scrutiny (Mossman 1996; Griggs 2017). Neither IMP modification nor a basin approach was adequate for Kansas.

In 2010, Kanas filed another petition against Nebraska with the Supreme Court with three claims. One, that Nebraska was in contempt of the Compact and the FSS for 2005 and 2006; two, Kansas wanted damages based on Nebraska's gain and a mandatory shutdown on 170,000 acres of groundwater irrigated acreage; and three, fixed penalties for future violations and a river master assigned until Nebraska fundamentally changed their groundwater laws (Blankenau 2010; Griggs 2017). Nebraska challenged Kansas for the accounting procedures and cross-claimed against Colorado for water (Griggs 2012). Its counterclaim alleged that because the accounting procedures were flawed, the state was being charged for water consumption that had originated in the Platte River basin (Griggs 2017).

In turn, Nebraska has constructed and begun using two groundwater augmentation pipelines (Rock Creek and N-CORPE) to fulfill its obligations at the expense of its surface water users and in opposition to Reclamation (RRWCD 2009; Knapp 2013; Griggs 2017; N-CORPE 2017). N-CORPE is a $120 million project (between the four NRDs in the basin) that uses 30 high capacity groundwater wells on the northern edge of the basin adjacent to the Platte River basin. It sends water through pipelines to Medicine Creek and began operations in 2014; water can also be sent to the Platte River (N-CORPE 2017; Figure 4.12). Rock Creek began operations in 2013 and is operated by the Upper Republican NRD; it has 10 wells and empties into the North Fork of the Republican River (N-CORPE 2017). Colorado's preemptive, voluntary, and difficult response to meet Kansas's water requirements was to drain Bonny Reservoir on the South Fork of the Republican River in fall 2010 into spring 2011, retire surface water wells, and construct a compliance pipeline that uses groundwater (RRWCD 2009; KDA 2016a). In 2015, the U.S. Supreme Court ruled that Nebraska owed Kansas monetary damages for overuse ($5.5 million), but did not need to shut down wells or have a temporary River Master assigned to oversee basin activities (*Kansas v. Nebraska, 135 Supreme Court*), but each state claimed victory (Hendee 2015; Knapp 2015). An important note, however, is the Supreme Court dissent response. It contends that there was no water miscalculation, that Nebraska simply wanted full credit for any supplemental created water like augmentation or seepage from the Platte into the Republican (Griggs 2017).

At this writing, together the three states and the RRCA have taken two positions. One, they oppose Reclamation who is charged with protecting the irrigation districts (NBID and KBID). Two, the RRCA has allowed Nebraska to subvert its Compact duties by receiving 100% credit for groundwater augmentation, even though losses occur via evaporation and transport, and epically failing to support its Compact surface water farmers by shutting down surface water rights as opposed to groundwater rights (Griggs 2017).

Figure 4.12. N-CORPE Augmentation Project Outlet at Medicine Creek, Lincoln County, Nebraska (UNL Water Center 2013).

A case in point is the 2017 Nebraska Supreme Court ruling in *Hill v. Nebraska and Nebraska DNR* (296 Neb. 10). The suit was filed because both 2013 and 2014 were Compact Call Years (surface water rights closing notices are issued) based on the NDNR's water forecast calculations, so the Frenchman-Cambridge irrigation district and irrigators essentially had no surface water for irrigation. The court found that Furnas County irrigators and the Frenchman-Cambridge Irrigation District could not claim that one, the state and NDNR had illegally taken their rights to surface water under the Nebraska constitution because the Compact as a federal statute supersedes individual water rights, and two, the NDNR, again under the state constitution, does not have jurisdiction to control groundwater. In fact, there is no central authority that controls groundwater in the state rather it is under local control. The recent ruling points to the dominance of groundwater, the inability or unwillingness of the state to more closely regulate groundwater use (legislative action), the need to fulfill Compact obligations at the cost of surface irrigators, and the fact that surface water irrigators in Frenchman-Cambridge and Nebraska Bostwick Irrigation Districts have very limited avenues to address orders and closing notices that directly impact their livelihoods.

These positions have political, legal, and hydrological ramifications at all scales for local growers, the federal courts, state agencies, losing streams, and depleted aquifers. Until state citizens and legislatures have meaningful water policy dialogues about *all* of water's facets, surface water users will be the initial losers. Eventually everyone loses when the water is no longer accessible or replaceable.

WATER POLICIES CONCLUSION

Water law and policy in all three states continues to undergo transformations through amendments, statutes, and repeals. The challenge facing Kansans as well as Nebraskans and Coloradoans on the Great and High Plains is not so much a question of individual rights, but how those rights fit into a changing environmental and demographic reality. For example, Colorado is expected to add 2.8 million people by 2030, pushing the state population to 7.1 million. Nearly 87% (2.4 million) of those people will be in the eastern half of the state requiring an additional anticipated 630,000 AFY or 205.3 billion gallons of water more per year for municipal and industrial use. By 2050 the state population will be 10 million and updated projections suggest 538,000 – 812,000 AFY more for municipal and industrial use (Jones and Cech 2009; Colorado Water Conservation Board n.d.a., n.d.b.).

Agricultural land sales near Front Range communities garner attention more for their water rights than for the land itself (Worthington 2016). Growers in the San Luis valley have taxed their water use paying $75 per acre-foot pumped water plus $8 for each irrigated acre, and reduced their pumping by 30% (Runyon 2017). Technological advances in water delivery for agricultural efficiencies such as using the same amount of water to produce higher yields and seed genetics that allows plants to develop for longer periods of time between receiving water are helpful, but water once lost is difficult to replace. Precipitation fluctuates, droughts are unpredictable, some aquifers are essentially non-renewable at current withdrawal rates, urban demands outpace local water resources, and agricultural economics and aging populations mean the face of the Great Plains and its water resources and uses will change. There are limits to both surface and groundwater use. Nothing can be done about how the Republican River's water is allocated between the states; it is a fixed consumptive value. The Compact has no incentive for water conservation. Re-negotiation based on newer and better science, changing agricultural and water management practices, and shifting environmental conditions could be undertaken, although the RRCA could adopt rules that reflect such changes. The likelihood of any state voluntarily choosing a "new" compact over known advantages and disadvantages is doubtful. How the states choose to face their competing internal water demands is up to each state, but there could be ramifications for compact compliance. Internally, fair and equitable today may not be fair and equitable for future generations. Water rights compensation may be at the expense of urbanites and others who pay state and local taxes, and preserving water quantities and access may inflict hardships upon current generations to provide livelihoods for later state and plains citizens. Neither solution is easily undertaken, but they highlight situations that could arise in the future.

Water resources are fluid, necessary and may be damaged by human activity. Since water disregards political borders, transboundary conflicts result. In the Republican River valley, the political boundaries that form the states, resource districts, counties, and irrigation districts override the basin's physical boundaries. Therefore, water is subordinated to an artificial and arbitrary human border. Further, the socio-hydrologic relationship is based not only on resource location, but human activity in the form of agro-economics and politics, each of which dominates the basin's hydrology.

Prominent water resource policy scholars Edella Schlager, Tanya Heikkila and colleagues provide insights to interstate compacts, conflicts, and Western water that have bearing on the Republican River situation that include reducing economic and political costs, polycentric governing as more cost effective for states, and adaptability under changing climatic conditions (Schlager et al. 2012; Schlager and Heikkila 2011). They suggest that interstate water compacts don't match the settings for which they are devised. Compacts assume streamflow stability for long-term sharing, but they anticipate continued downstream versus upstream conflict due to changing precipitation, increased use, or both. The largest challenge may be climate change and state responses to changing streamflow under restrictive compact requirements such as specific flow requirements at state lines (Schlager et al. 2012). Solutions to these anticipated problems include renegotiation (unlikely), information sharing, accessible conflict resolution, and coordinated water action across state political lines (Schlager and Heikkila 2011). In reports from the IPCC and the U.S.

National Climate Assessment (IPCC 2013, 2014; Melillo et al. 2014), anthropogenic activity has impacted environmental conditions such that increasing temperatures and decreasing precipitation is anticipated, further complicating the socio-hydrology relationships and feedback loops. These in turn will influence the intensity and frequency of potential transboundary water resource conflicts.

The basin perspective for water challenges and conflicts has been presented with a wide-angle lens, but for the day-to-day users in the basin who work with these challenges on a personal basis it is always a micro-lens. Transboundary conflicts and depleted or damaged water resources have real and immediate impacts with short- and long-term sustainability consequences. Reasonable and workable solutions are needed in order to prevent irreparable breaks to people, their livelihoods, and the physical and hydrological systems that support them. If either system fails or becomes unusable, people fail too, so it behooves managers and decision-makers to work collectively with all actors to craft feasible and effective state laws, policies and regulations that benefit the state and its Compact obligations. It is the physical environment and climate along with economic and social drivers that ultimately shaped water law in the West (Hess 1916), their co-evolution in turn defining their socio-hydrology relative to the landscape. Understanding the historical context of events within the states and those that are directly tied to the Compact may help us be better prepared, if not to meet the future, at least see it on the horizon.

Chapter 5 continues the theme of water law and policy by assessing the Compact and FSS and their likelihood of implementation success.

CHAPTER 5
STATUTE IMPLEMENTATION ASSESSMENT

Policy implementation is not easy; it is dynamic and fluid. The three states governed by the Republican River Compact have worked together externally through the RRCA to meet and address Compact stipulations while internally designing state statutes and regulations to meet those obligations. Adjustments and compromises at local and state scales have become necessary, as water use, water access, technology, and environmental conditions have changed since the Compact's 1943 inception.

The 1998 *Kansas v. Nebraska* case saw Kansas challenge Nebraska about groundwater impacts. It was the first time one state had challenged another under the Compact. The most significant result was the 2002 Final Settlement Stipulation for the joint development and implementation of a groundwater model to assist the states with their annual water use to remain within Compact limits. The second federal challenge was the enforcement of the 2002 FSS in the 2010 case *Kansas v. Nebraska* where Kansas sought damages against Nebraska's overuse of water in 2005 and 2006 (35,000 acre feet each year). The 2015 decision was a $5.5 million disgorgement from Nebraska to Kansas for accrued financial losses. Second, Nebraska did not have to reduce its groundwater irrigated acres by 170,000, since the Court felt that Nebraska's legislative remedies (IMPs) were currently adequate (Griggs 2017). Challenges to the Compact's application are ongoing between agencies and actors over water allocations, policy interpretations, power, jurisdiction, and legal and Compact intent; in 2016, there were four court filings in Nebraska related to the Compact. These legal challenges at the federal and state scales attest to the difficulty of implementing statutes under fluid environmental conditions and often times rigid regulatory constraints. It is especially trying with the Compact, as it remains in its original form since ratification; the FSS accounting procedures served to clarify some Compact expectations.

Public policy research highlights the fact that implementation of existing law is not a given, even with the limited formal federal challenges to the Compact. Laws and regulations can be purposefully designed and structured to maximize the likelihood of successful implementation or to maximize delay and a pre-law *status quo*. Further, older laws like the 1943 Compact could not necessarily foresee future scientific, technical, or environmental changes that would challenge the character of the agreement. Policy implementation theory suggests that a careful exploration of the broader context of a statute's situational position can reveal much about the likelihood of a statute achieving its goal. A policy implementation assessment of the Compact and the FSS can provide such context.

From a legal perspective, the U.S. Supreme Court views both the Compact and the FSS as legal contracts between the states. That lens differs from that of social science and policy implementation research whose rubrics for analysis may be considered functionalist and abstract, since they may not include historical and legal context for evaluating a statute or contract. Nonetheless, undertaking an analysis with a policy implementation perspective and tools can provide new and alternative insights to how statutes are interpreted and applied.

Policy process theories focus on different dependent variables like policy change, implementation, or statute passage and adoption. Overall effectiveness, monetary cost-benefit analysis or policy outputs are common measures whether undertaken from an economic, political, policy, research, or corporate position.

Approaches can be top-down or bottom-up. In social science, policy process theories include Rational Choice and Institutional Rational Choice (IRC), Institutional Analysis and Development (IAD), Common Pool Resources (CPR), Punctuated Equilibrium, Advocacy Coalition Framework, and diffusion models (Sabatier and Weible 2014). These same theoretical policy process approaches have been applied to natural and environmental resources that are subject to geographies of scale such as extracting common pool resources or interstate compact success. Air, water, timber, fossil fuels, pollution, mining, and fisheries are just a few resources that are subject to policy-based regulations. How those policy statutes and regulations are written and implemented can determine their success. For example, studies have been undertaken for forestry, marine ecosystems, resource co-management, socio-ecological systems, and wildfires using these policy process theories (see Klooster 2000; Busenberg 2004; Folke 2006; Cashore and Howlett 2007; Olsson et al. 2008; Weible et al. 2010; Sotirov and Memmler 2012).

Policy assessment is important because it helps us understand why some policy implementations are successful and others are not. It can facilitate crafting new or amending old policies to achieve a desired outcome. Undertaking a policy assessment of the Compact and FSS in conjunction with their impact on the irrigation districts of interest, i.e., the Bostwick and Frenchman-Cambridge, is appropriate. The districts are directly impacted by any decisions made by their states or the RRCA. Because they are not explicitly named in the Compact, the Nebraska DNR can choose to limit the Nebraska Bostwick and Frenchman-Cambridge Irrigation Districts' surface water access at virtually any time as long as proper notice is given to the district and their irrigators. By so doing, Nebraska fulfills its water obligation to Kansas at the expense of its own growers. Without specific inclusion in the Compact, the districts are essentially shut out of any decision-making process.

I employ Mazmanian and Sabatier's (1981) theoretical policy process lens to examine the Compact and FSS, specifically how a statute's or legal document's legal language does or does not provide clarity of guidance for implementation. The theory provides a framework that moves towards predicting the likelihood of statute success. My findings are important because they offer an additional avenue to explore and deconstruct statutes, provide a means to examine transboundary water conflicts, and contribute to a better understanding of the Compact's role in the basin's socio-hydrology.

The remainder of the chapter is divided into four sections. First, I place the Compact and the FSS within the context of the basin itself to provide a sense of place and to identify some of the socio-hydrological relationships. Second, I describe how I adopt Mazmanian and Sabatier's methodology. Third, I assess statute implementation. It is divided into two major sub-groups, the Compact and the FSS. The chapter ends with a discussion and conclusion.

SOCIO-HYDROLOGICAL SETTING

Most directly impacted by the Compact and its associated regulations are three basin irrigation districts — Nebraska and Kansas Bostwick Irrigation Districts and the Frenchman-Cambridge Irrigation District, none of whom are directly named in the Compact. The districts are in Bureau of Reclamation divisions for the Pick-Sloan Missouri River basin project (USBR 2017b). The Compact's objective is to equitably allocate the virgin waters of the basin between Colorado, Kansas, and

Nebraska. The Compact's framers envisioned irrigation development in the basin as largely limited to surface water and canals based on streamflow estimates of the time and the difficulty of accessing deep groundwater (Ann Bleed, former Nebraska DNR Director, pers. comm. 2016). Under those conditions they calculated that there would be adequate water supplies for irrigators and growers. However, the later development of well-pumping technology and center pivot irrigation allowed groundwater to be tapped and mined to irrigate upland and marginal acres of the basin rather than remaining concentrated in the flood plain and lower valley, the alluvial plain (Schafer 1993; Getches 2009; Jones and Cech 2009; Kromm 2011; Korus et al. 2013). Increased groundwater use has led to a lower water table, and in some places the fear of severing the hydrological connection between surface and groundwater, leading to not only decreasing streamflows, but groundwater depletions (Bentall and Shaffer 1979; Harnsberger and Thorson 1984; Moody et al. 1989; Aiken 2006; McGuire 2009; Konikow 2013; Castle et al. 2014; KGS n.d.). The Compact as initially envisioned could not have foreseen the technological developments that have changed the basin's waterscape. Climatic patterns and periodic drought have also impacted streamflow and surface water in both short and long-term periods most recently in 2000-2005 and 2012 (Burbach and Joeckel 2006: NOAA 2013; Figure 5.1). Alluvium and groundwater recharge are affected when groundwater is extracted at rates greater than it can be replaced plus farming practices such as no till, terraces, and farm ponds retain water and can slow recharge. These factors and others beyond actual governance play a role in the basin's socio-hydrology, but provide context for statutory implementation. At the same time it acknowledges that theoretical applications may not always be able to accommodate contextual and situational factors.

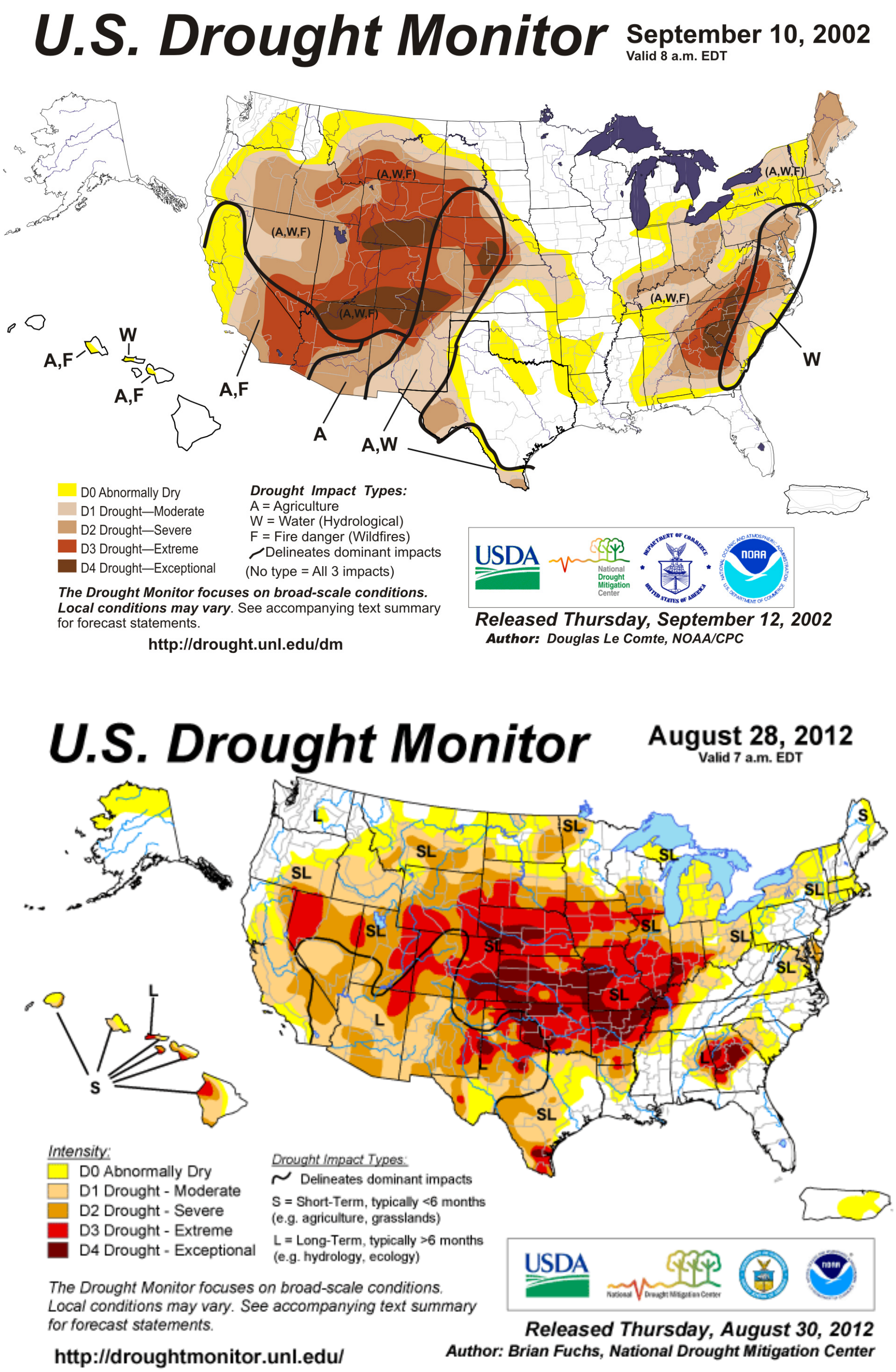


Figure 5.1. U.S. Drought Monitor, 2002 and 2012 (NOAA n.d.c. 2013).

The bulk of the chapter is contained within the next two sections. It begins with a methodological description of the theory and the components that I use for my policy assessment. Next, two assessments are undertaken, one on the Compact and the other on the FSS. For each document's assessment, tables display statutory structural implementation factors, representative descriptions from the documents that illustrate the factor, and an individual score or rank for each factor. Each document assessment includes factor discussions.

ASSESSMENT METHODOLOGY

Mazmanian and Sabatier (1981, 1989) offer a policy implementation analysis framework and methodology that provides insight about the likelihood of policy success based on the structure and language used in the statute itself and other important variables (Figure 5.2). Theirs is a top-down approach that examines policy from a centralized hierarchical position (Alterman and McRae 1983; Goggin 1984), expands upon earlier calls for policy implementation theory (Pressman and Wildavsky 1973; Van Meter and Van Horn 1975), and has been empirically tested with various policies such as statutory and non-statutory environmental regulation (Goggin 1984; Sabatier 1986; Mazmanian and Sabatier 1989; Winter 1990; Elson 2005; Zhang et al. 2011; Wakita and Yagi 2013; Carter et al. 2015). In the case of the Compact, the centralized hierarchy and its associated power is the Compact document itself because it is supported by federal force, it is a federal law. Local forces such as state legislatures and various other agencies have important roles as well, but they are subordinate to the Compact's power. As yet, an examination of the Compact with a distinct understanding of its legal power has not been undertaken with a policy implementation assessment lens. My policy research assessment takes on that task.

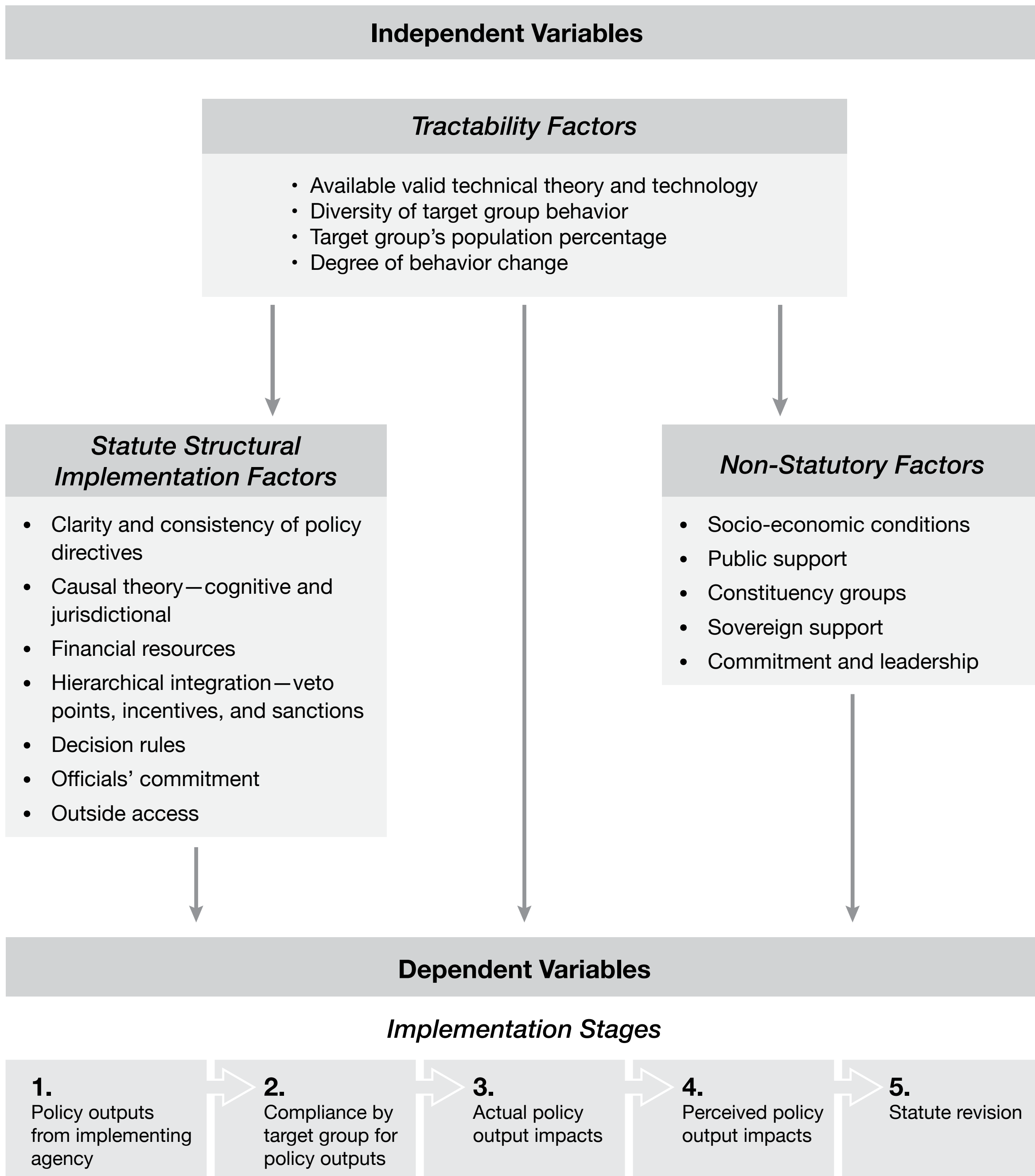


Figure 5.2. Mazmanian and Sabatier Policy Implementation Analysis. Based on Mazmanian and Sabatier (1981, 22) (Author).

Mazmanian and Sabatier offer three broad areas under which important independent statute or policy variables are identified: "(1) the tractability of the problem(s) being addressed; (2) the ability of the statute to structure favorably the implementation process; and (3) the net effect of a variety of political and social variables on the balance of support for statutory objectives" (1981, 21). All are built on the premise that "the implementation process is the rational pursuit by individuals of their desires for power, security, and well-being" (1981, 20). Studies that include Mazmanian and Sabatier's independent variables and their factors range across disciplines and are not exclusive to their framework, as illustrated in the factor overviews that follow.

Tractability covers technical difficulty, target groups, and behavior change. In particular, tractability can highlight and capture local dynamics that influence statute implementation challenges. Target group research is frequent and diverse and can include statute implementation studies, since a statute is often designed to impact them; ample examples exist and are not needed here. A behavioral change study examined intergroup perceptions at three different points over a 17-year period to assess how collaborative and adversarial group policy-making perceptions changed. One finding was that positive perceptions were more likely to occur after collaborative policy-making, and that time was a factor (Weible et al. 2011). Numerous other studies exist as well, as they do for technical challenges.

Structural implementation covers objectives, causal theory, finances, integration, rules, and access. Two studies serve as examples. First, federal incarceration outcomes based on cumulative U.S. Supreme Court rulings have shown a causal relationship in district courts (Hall 2017). Second, climate change mitigation and adaptation in Dutch cities are less likely outside the four largest cities because of municipal decentralization, external initiatives, and regionalization that have shifted the hierarchical integration (den Exter et al. 2015).

Non-statutory variables contain socioeconomic conditions, constituency groups and support, and leadership commitment. For example, oil extraction royalty distribution practices for regional development in Italy based on regional governance policies have not noticeably changed the socio-economics of the region (Rocchi et al. 2015). Here a non-statutory factor, socio-economic, is connected to structural implementation via financial resources.

Research across disciplines and topics incorporate elements of Mazmanian and Sabatier's theoretical framework without formal adoption of the theory itself. Regardless, policy variables and factors are studied extensively in order to understand the causes and consequences of policy, as these examples have shown. Tractability, non-statutory variables, and structure implementation are all independent variables that influence implementation stages and the likelihood of policy success. Changes in any of the three due to its own internal factors creates a ripple that may or may not be offset by other elements and influence statutory success, so understanding the context and conditions of any research study is important.

Likewise, water resources and associated policies can be approached from a variety of perspectives. Their policy regulation is difficult because water is spatially dynamic and transitory changing from solid, to liquid, to vapor across physical and social borders. Water evaporates from soil and the surfaces of lakes or streams and with gravity it runs downstream either at or below the land's surface making it difficult to physically and politically bound water in space. As a result, water's behavior adds to the tractability of the problem.

Trans-boundary water studies occur at all scales, covering a variety of conflicts from quantity, quality, water rights, legal documents, power dynamics, and resolution options to issues of globalization and commodification (Swyngedouw 1997; Matthews 2005; Bush et al. 2007; Dellapenna 2007; Schlager and Heikkila 2009; Hathaway 2011; Katz and Moore 2011; Heikkila and Schalger 2012; Mooney and Tan 2012; Schalger et al. 2012; Sheelanere et al. 2013; Petersen-Perlman et al. 2017; Zeitoun et al. 2017). Policies are a part of those conflicts. I give two relevant examples. Milman and Ray (2011) studied the Santa Cruz Aquifer that is accessible to U.S. and Mexican users who live in the states of Arizona and Sonora, respectively. They used hydrological data and interviews with people from both places. The water data, management, policies, and regulations for this shared aquifer differ, as do perceptions about groundwater availability, longevity, recharge, and other factors. A collaborative approach to the aquifer would be advantageous to each location, but instead the U.S. and Mexican water managers promote unilateral policies. Although this highlights an international challenge, the basics of the situation are applicable at any scale or location. Allison Sambol (2010) interviewed residents of the Republican River basin after the 1998 Kansas lawsuit to determine how or if opinions varied on each side of the Kansas-Nebraska border for this shared water resource. Based on interview responses, she concluded that court disputes and settlements were not meeting the needs of the basin's residents, and that they were willing to work together to solve water scarcity issues. Although not explicit in either of these studies, the legal language, statute structure, and resulting regulations are important drivers for successful policy solutions to water resource conflict, management, and users.

My research is the first use of Mazmanian and Sabatier's structural implementation approach focused exclusively on the Compact's parsimonious language and the FSS's more expansive language to examine how it has shaped implementation and overall success (or not). By utilizing it, my work broadens policy implementation analysis and offers an avenue to discuss transboundary disputes and resolutions by specifically deconstructing the Compact's legal language. Together, they contribute to building a socio-hydrological profile of the Republican River basin.

Since my assessment focuses on structural implementation, a brief description of its seven factors is helpful. They are provided in table format and include the assessment questions I am pursuing relevant to the Compact and FSS (Table 5.1). Questions can be applicable to the documents individually or for each of them. Factors are evaluated on a scale ranging from high, moderate, low, and neutral based on Mazmanian and Sabatier's scale, and I define them as follows. High is interpreted to mean there are few if any inconsistencies, the language is clear, and implementation is likely. Moderate equals some language factor inconsistencies or concerns exist that may interfere with implementation or cause delays. A low rating implies extensive language obstacles and frequent ambiguous language or directives that will noticeably impede or prohibit implementation. A neutral score indicates the factor's language has little or no impact on statute implementation. Statute implementation success is most likely when the independent variables and their associated factors illustrate moderate to high scores.

COMPACT STATUTE ASSESSMENT

The Republican River Compact is a simple document that contains 11 articles, including its purpose, definition of the basin, and making water allocations along with provisions for the Compact's administration. Ratified in 1943 by the U.S. Congress, it sets forth an agreement between the three states over how the waters of the basin are to be divided for annual beneficial consumptive use in acre-feet. The 2002 Special Master's FSS in its entirety is a five-volume report further specifying allocations, timing, and accounting procedures that were not addressed in the original Compact (Blankenau 2010; Griggs 2012, 2017; RRCA n.d.a., n.d.c.). The main FSS document references 13 appendices that include schedules, maps, state laws on well construction, and water year plans. I assess the seven page Compact and the 40-page FSS that describes the overarching components of the settlement. The statute and agreement once confirmed and ratified required policy implementation at spatial and temporal scales dependent on the document itself. Successful implementation is not guaranteed and is itself reliant upon the language of the statute and its interpretation by government bureaucrats and those actors who must design, enact, and enforce the policy.

The statute and agreement are assessed with two overarching questions: one, do they include a specific service such as infrastructure or regulate a specific type of behavior such as equitable water use, if so what and how; and two, does the statute and agreement attain their objectives, and if so, how are they achieved (Mazmanian and Sabatier 1981). I anticipate that the language and structure of the two legal documents will be adequate to facilitate reasonable implementation. I discuss the answers in the chapter's conclusion.

Table 5.1. Structural Implementation Factor Description and Assessment Questions

1. CLEAR AND CONSISTENT DIRECTIVES
    - Refers to the importance of the statute's objectives and goals, can assist agencies in their application of the statute, points to potential inconsistencies, and identifies the statute's priority status.
    - Are the statute's objectives identified and clearly stated? Are they prioritized? Do they provide implementation guidance?

2. VALID CAUSAL THEORY
    - Addresses the connections between government intervention, achieving successful implementation, and providing adequate jurisdiction enforcement. It has a cognitive component, recognition of the problem and relationships to its solution, and a jurisdictional component, focused on assigning appropriate power to agencies or officials for implementation.
    - Is there a linked sequence of activities that will lead to statute success? Is jurisdiction assigned to match the scale of the problem?

3. FINANCIAL RESOURCES
    - Sets initial funding levels that provide for staffing and research. Unless it is guaranteed, renewal and appropriations are often up to legislatures.
    - Are there adequate financial resources to support and achieve statute success?

4. HIERARCHICAL INTEGRATION
    - Refers to the ability of the statute to incorporate multiple agency cooperation. Veto points (the ability to overrule or object), incentives, and sanctions influence inter-agency cooperation to meet the statute's goals.
    - Do the instituting groups have decision-making control? Are there incentives and sanctions? Are they enough to encourage cooperation? Can they be monitored and enforced?

5. DECISION RULES
    - Identifies requirements and guidelines that can assist agencies in achieving success.
    - Are decision-making criteria and guidelines included? Are they supportive of the statute's goals and objectives and for successful implementation?

6. OFFICIALS' COMMITMENT
    - Refers to administrative persistence and fit, need for program support, and ideal assignment to an agency with a similar mission and agenda.
    - Are guidelines for administrative assignment and action provided?

7. OUTSIDE ACCESS
    - Provides a mechanism for people who are not part of the agency implementing the statute to either support or challenge it.
    - Are access opportunities for outsiders identified and included?

(Mazmanian and Sabatier 1981; Carter et al. 2015)

I present a tabulated assessment for the Compact and FSS documents individually with representative quotes from the documents themselves or summary statements to illustrate how factors do or do not fulfill Mazmanian and Sabatier's policy implementation framework (Tables 5.2 and 5.3). For example, in assessing the Compact's clarity and consistency, Factor One, I describe the language as ambiguous and quote "most efficient use of the waters for multiple purposes" to support the description, while others may be statements or conclusions like "no clearly identified target groups." A discussion of the factors' assessment and ratings follows each table. Tractability and non-statutory variables are discussed jointly in Appendix A to provide a simple assessment of those two independent variables and the larger framework.

Compact Statute Assessment Results and Discussion

The Compact scores Low on my adapted Mazmanian and Sabatier's implementation scale, since none of the factors provide enough detail and specificity about goals, objectives, techniques, or other elements. The statute's language and intent is simple and focused on then-current 1940s conditions and practices, with little anticipation or foresight regarding potential conflict whether it be political, socio-economic, or hydrological. However, Delph Carpenter did have the foresight to propose interstate compacts (Tyler 2003; Rettig 2017a); without them more litigation among states likely would have been more prevalent. None of the factors and their variables is fully addressed. All the factors lack specificity and it has directly led to conflict between the states, notably the U.S. Supreme Court lawsuits that have addressed the lack of specificity (discussed with the FSS assessment). In part it may be attributable to a gap between the nature of the problem and its proposed solutions. As a legal contract between the states, standard contractual language is embedded further clouding some elements of specificity. The Compact recognized the administration of the Compact through each state's water administrator, and the states later formed the RRCA pursuant to Article IX. However, the jurisdictional power to impose sanctions on any partner state and avoid expensive federal lawsuits is weak. As a result, the states squabble amongst one other, since they can veto proposals from the other states and their arbitration process is non-binding. Whether or not the veto option was included to undermine implementation is difficult to address; it protects individual states but at the expense of the others and the basin's water. See Table 5.2 for each factor's specific assessment and examples.

CLARITY AND CONSISTENCY

Article I of the statute sets forth goals that lack clarity and specificity. For example, the phrases "remove all causes that might lead to controversy" and "promote comity" are undefined. Three federal compact cases at the time could have provided substantial guidance in that area. Colorado and Kansas were continuing to battle over the Arkansas River (*Kansas v. Colorado* 1902-1907 and *Colorado v. Kansas* 1943-44) and Nebraska and Wyoming were feuding over the North Platte River. (*Nebraska v. Wyoming* 1945). These cases could have helped to address future water controversies. These issues remain unaddressed by the Compact. Goals exist as a list without prioritization in Article I. A reader may infer that the first one in the list is the most important, most efficient use for multiple purposes rather than the last one, joint action for efficient use and flood control. Thus, each State can determine how they want to prioritize the goals, rather than having a single system. Without explicit priorities there exists the potential to undermine the Compact's intent of equitable allocation.

Equitable division of the basin's water does receive more attention in Articles III and IV. Each drainage basin has a calculated acre-feet based on average annual virgin water supplies, sub-divided and allocated to a State proportionally based on what percentage of a basin is within its political borders. There is some reference to changing physical conditions whether by man or nature and how to adjust allocations. Groundwater wells and their impact on surface flows has been the most contentious state issue, particularly during droughts and periods of below-normal precipitation. All sub-basin allocations are for beneficial consumptive use, one of three defined terms. While the goals are admirable given the time period, they lack dimension.

Table 5.2. Republican River Compact Policy Implementation Assessment

Structure Implementation Factors and Score	Republican River Compact, 1943 Structural Implementation Examples
1. Clarity and Consistency of Policy Directives *Low*	*Ambiguous objective prioritization and clarity* • most efficient use of the waters for multiple purposes; • remove all causes that might lead to controversy; • promote interstate comity; • recognize that the most efficient use is for beneficial consumptive use, <u>although state law provide guidance;</u> • promote joint action for efficient use and flood control.
2a. Causal Theory: Cognitive — the problem *Low*	*Limited and inadequate problem recognition* • only 3 defined terms: acre-foot, virgin water supply, beneficial consumptive use; • no time limits or guidelines <u>because it is considered perpetual;</u> • no clearly identified target groups; • limited non-statutory variable inclusion; • limited technical means.
2b. Causal Theory: Jurisdictional — adequate power *Low*	*Imprecise jurisdictional control and authority* • administered by the State official in charge of public (state) water supplies; • States have greatest control; • U.S. can use water beneficially (under state law) but it is charged to the State in which it is used.
3. Financial Resources *Low*	*Absent initial or ongoing appropriations process* • Facility repair and replacement subject to upper State laws; • U.S. exempt from State taxes or loss of State taxes.
4a. Hierarchical Integration: Veto Points *Low*	*Multiple actor veto points* • requires ratification by State Legislature and U.S. Congress; • water storage or diversion projects in an upper State by a Lower state subject to upper State's laws; • rules and regulations must have unanimous approval from all State administrators; • States cannot hinder U.S. rights, powers and jurisdiction in the Basin, including the ability to acquire rights and use water in the Basin.

Table 5.2. (continued)

STRUCTURE IMPLEMENTATION FACTORS AND SCORE	REPUBLICAN RIVER COMPACT 1943 STRUCTURAL IMPLEMENTATION EXAMPLES
4B. HIERARCHICAL INTEGRATION: INCENTIVES AND SANCTIONS *LOW*	*No incentives* *Limited sanctions* • States can file lawsuits against other Compact States if the terms of the Compact are violated. o No exercise of power or right that would interfere with beneficial consumptive water use. • No enforcement mechanisms and the rights of the U.S. are unclear.
5. DECISION RULES *LOW*	*Limited guidelines and requirements* • A state official who is charged with carrying out the duties of the Compact; • All 3 state officials unanimously may adopt rules and regulations; • USGS collaborates with states for collection, correlation, and publication of water facts for Compact administration.
6. OFFICIALS' COMMITMENT *LOW*	*Two references to administrative needs* • A state official to administer public water and associated activities such as data collect; • USGS will collaborate with state officials for proper Compact administration.
7. OUTSIDE ACCESS *LOW*	*No identified outside actors or mechanisms for engagement*

Key: High = stronger asset for implementation; Moderate = reasonable asset with some potential problems; Low = unlikely asset with notable problems; Neutral = little impact on implementation.

CAUSAL THEORY

The relational connections between the problem's cause and how to solve the problem is poorly done; problems have limited explanation throughout the document. Not even the catalyst for the Compact is included in its opening: "The States … having resolved to conclude a compact with respect to the waters of the Republican River Basin." Few solutions are offered through the Compact's language and structure, even some may argue that the allocation is the solution. However, without a direct recognition or statement of any initiating events, other than the fact that the three states share the basin, it is difficult to see how an allocation can be the sole solution to potential problems.

As written, the target group appears to be the three states and makes no direct mention of other stakeholders in the basin other than a few references to persons or entities that could be interpreted to include current and future irrigation districts. (Legally such language and presentation is intentional under constitutional law since states speak for their citizens.) In this way, the states can be perceived as monolithic entities without any checks and balances provided by outside actors whether ordinary citizens, interest groups, or irrigators. Consequently, adjustments due to shifting demographics, variable economic conditions, new scientific data, and changing water quantities due to environmental conditions invite conflict either internally or between the states.

Nebraska's Frenchman-Cambridge and Bostwick Irrigation Districts (FCID and NBID), as basin stakeholders and potential target groups, have filed multiple lawsuits against Nebraska and its agencies. For example, in 2014 four members of the FCID sued NDNR for halting the district's surface water storage and diversion permits and letting groundwater pumpers over-use groundwater, claiming that such an action was 'inverse condemnation' of their water rights. Irrigation users have been denied surface water for five years beginning in 2013, each of them a Compact

Call year. A Compact Call or Water Short Year occurs when the NDNR determines that there will not be enough water moving downstream to Kansas from Nebraska. As a result, they issue a closing order to surface water irrigators in the basin (NDNR 2016, n.d.). The Furnas County District Court dismissed the suit in 2016, and it was upheld upon appeal to the Nebraska Supreme Court in 2017, who noted that the federal Compact takes precedence over Nebraska laws (Raun 2017b). As growers in the district say, "We don't like court, but it's the only way we're heard — threat of financial settlement. [We] don't want to spend $5-10 million per year. Get someone to fix this. We've been forced to do this. Liability gets attention" (Grower 7). "All the [Nebraska] senators [pay] attention when money is involved, not just the rural ones" (Grower 8). "[The] basin's represented by one, two, three senators, [we] need Omaha senators" (Grower 7). Were any of the irrigation districts specifically included or named and therefore protected by the Compact, a different result would have occurred and the socio-hydrological relationships of the basin would have taken on a different character. Although the quote highlights challenges in Nebraska and not the Compact directly, it does not preclude future legal proceedings that could directly involve the Compact.

Furthermore, new infrastructure projects such as dams, reservoirs, canals, and diversion ditches would subject agricultural producers to impacts. Any agricultural producer in the basin who used surface flows would certainly have qualified as a stakeholder at the time of the Compact's initiation. At the present time, they expect to provide commentary and input for changes that directly impact them. However, the irrigators and districts have no real power to ensure that their input will become or even influence a management strategy or state policy. Currently FCID and NBID experience more burdens than benefits based on the Compact's language (Schneider and Ingram 1993, 1997; Welsh and Endter-Wada 2017a). Because it is a legal document among the three states, some ambiguity is expected in regard to target groups to preserves states' rights, but it severely limits the likelihood of support by on-the-ground users if terms are not defined. Nebraska has been especially astute at leveraging the lack of definition for either surface water or groundwater, contending for decades that the Compact included only surface water, that surface water and groundwater were not hydrologically connected, and granting thousands of groundwater permits in their portion of the basin. Strategic target groups can be key to a statute's successful implementation. Nebraska's strategy has resulted in intra-state water user battles among surface and groundwater users, Frenchman-Cambridge and Nebraska Bostwick, resources districts, and the NDNR.

During the Compact's initial development, various reports and documents were presented at the first four meetings of the Republican River Compact Commission by the states, Reclamation, the U.S. Bureau of Agricultural Economics and the U.S. Army Corps of Engineers. They pertained to equitable allocation, flood control, basin projects, irritated and irrigable acres, streamflow, project costs, and usability of underground waters some of which made their way into the Compact (RRCA n.d.c.). Mr. Burley from Agricultural Economics cautioned about future development, surface and underground waters, and potential reductions relative to surface water availability (RRCA n.d.b.).

While it does include a few more specifics, jurisdictional clarity is as indistinct as the relationship between the problem, the solution, and target groups because only one Compact enforcement action is included — lawsuits. Even though there is a

Compact administration consisting of state representatives who have voting privileges, power is not concentrated there. In fact, it took 17 years after ratification before the states met to design protocols for virgin water supplies (Blankenau 2010). It is reasonable to leave internal organization to the states to preserve their rights in the form of water law and agencies. The RRCA can be seen as one means to address how the states should interact together for solving basin problems without lawsuits, but without unanimous action by state officials lawsuits may be the only recourse. State administrators will vary as will their internal duties; they are also subject to political winds of change. States retain a tremendous amount of power and authority to internally administer the Compact, block partner states from actions that may impinge upon them, and assess payment from partner states if a lower state constructs facilities in an upper state for the lower state's advantage (also a financial provision). If the U.S. uses water beneficially within a state, say Nebraska, the amount used will be charged against Nebraska's Compact allocation, and potentially limit water allocation for its own basin growers who are part of Nebraska Reclamation projects. Because the target group isn't identified beyond the state, irrigation districts and growers have limited external power in that they cannot sue another state, their home state needs to do so on their behalf. The clearest overall jurisdictional control is the Supreme Court, but states can address issues internally either legislatively or as the result of legal action.

FINANCIAL RESOURCES

Financial accounting procedures are also missing, and streamflow accounting is addressed through the allocations, a somewhat inadequate measure. Article IX is the closest to revealing how annual streamflows will be determined. State officials are charged with collecting data and administering the Compact for their respective State. There is no time frame associated with collecting and reporting data, nor the data type that needs to be collected within the basin. From the perspective of Mazmanian and Sabatier, it is an important omission because it speaks to the specifics of implementation and cooperation. Other components like technology, diversity, socio-economic conditions, or leadership can impact financial resources and the ability to successfully implement the statute. Since financial resources and procedures are lax, a gap is created that allows for multiple interpretations and misunderstandings to arise. Good causal theory requires linkages between government intervention or policy and the ability to attain program objectives, but they are missing.

As noted in Table 5.2, inclusion and reference to financial resources are brief, essentially confined to exempting the U.S. from State taxes or losses and requiring lower states to abide by upper state laws for facility construction, taxes, and maintenance. Construction, maintenance and operations typically are the responsibility of irrigation districts and States depending on how agreements were designed between them and other entities like Reclamation or the Corps. For example, $12.3 million of federal funding will fix 6 of 18 radial gates at Harlan County Dam that is controlled by the Corps (Potter 2014). Radial, or Tainter, gates control the water flow for dams and canals. Operations and maintenance costs are not insubstantial for irrigation districts, especially when age and life expectancy are included. Ongoing data collection to verify compliance, expert consultation, and legal fees are other costs associated with the Compact. Some acknowledgment of how known or potential costs will be apportioned for either inter- or intra-state responsibility could clarify financial obligations. In DiBaldassarre, Brandimarte, and Bevan's (2016) socio-hydrological model development, those social factors would qualify as known unknowns. Determining how to include variables like these is a major challenge.

Hierarchical Integration

Hierarchical integration like all the other areas of the Compact was concentrated in state power and the U.S. through state action, but no other stakeholders were included, therefore the ability of outside interests to participate and shape implementation is virtually non-existent according to Compact language. Irrigation districts would need the support of their state in order to partner with outside interests and effect change. Other potential outside actors could include farm bureaus, agri-businesses, and regional or national environmental organizations that would need to find back-channel avenues to shape implementation, in support of, or to challenge, Compact compliance. Such actions would be a Non-Statutory Variable but could still influence decisions. Veto points are closely tied to the previously discussed jurisdictional Causal Theory as well as Financial Resources. Incentives and sanctions were limited to one option, lawsuits, specifically were a State to "interfere with beneficial consumptive water use" or other Compact violation by another State. Inclusion of additional sanctions and incentives beyond the simplistic unanimous approval by State representatives would have been helpful in defining the roles actors can undertake.

Responses to Compact non-compliance since Kansas's initial 1998 suit against Nebraska and Colorado have included retiring groundwater irrigation wells, using augmentation projects (groundwater and pipelines) to enhance streamflows, requiring technology like well monitors and annual data reporting, designing or revising legislation to integrate surface and groundwater management in Nebraska, as well as on-going internal lawsuits in Nebraska between the irrigation districts, the Natural Resource Districts, the NDNR, and the Bureau of Reclamation in any combination. These actions reflect the Compact's lack of hierarchical integration as well as the states' subservience to the Compact as noted in the earlier Causal Theory discussion. Since there are no explicit incentives or sanctions for state behavior codified in the Compact beyond references to state laws, basin irrigation districts and users are left to navigate the Compact's legal waters without a compass, a boat, oars, or a life raft. In particular, surface water users are left adrift while groundwater users are offered better boats with more protections (Griggs 2017).

DECISION RULES, COMMITMENT AND ACCESS

For Decision Rules, Article IX references a rule for state administers to collect and collate data for "proper administration" through the public official charged with administering each states' public water supplies, but no specifics as to the type of data necessary are given explicitly in the Compact. It may be inferred that it rests upon each states' administrator's best judgment as to the scope, scale, and time of collection. Some latitude is recognized to "adopt rules and regulations consistent with the provisions of this compact" by the state administrators' unanimous action (an oblique reference to the Republican River Compact Commission or today's

RRCA), but no specific guidance beyond that statement is given. Thus, it is up to the state administrators to jointly agree upon appropriate data protocols. As a titration of bulky data, reports, and testimony, a compact document has to convey the essence of its purpose, and often that result is less than clear.

Officials' Commitment is recognized as a state responsibility for assigning an administrator who can oversee water issues as they pertain to the Compact. In Nebraska, it is the DNR director and Colorado and Kansas use their state engineer. The USGS is also included to the degree that they collaborate with the states to ensure proper administration. I am uncertain how much more specificity might be required in this document, since federalism allows states the right of internal management thereby creating internal challenges to meet Compact requirements. Mazmanian and Sabatier (1981) suggest that it takes 7-10 years for (successful) statute implementation, but requiring a fixed appointment for an official in a Compact would likely be considered onerous by the states. Outside Access is completely ignored, as noted above in the Causal Theory section and discussion of target group responsibilities and contributions. Potential for misinterpretation is possible with all three of these factors.

Each states' individual Compact behavior remained legally unchallenged and unclear for as long as it did for several reasons. One, most basin irrigators used surface water, so during shortages everyone suffered. Two, submersible pumps, center pivot irrigation systems, and other technology developed starting in the 1950s took time to develop and be adopted by basin irrigators into the 1970s and beyond (Manley 1993; Sheffield 1993; Aiken 1980). Three, the lag effect between technical advances for groundwater pumping implementation and subsequent decreased surface flows meant that surface impacts were not immediately noticeable (Figure 5.3). Once technology allowed efficient access to groundwater, state water statutes needed to be re-assessed to account for and regulate the activity if it did not already do so. Colorado and Kansas already had a single doctrine for surface and groundwater, prior appropriation, but Nebraska did not, using prior appropriation for surface water and reasonable use/correlative rights for groundwater. These and other associated issues culminated in 1998's *Kansas v. Nebraska and Colorado* (1998-2003), for which only the Compact applied. That result was the 2002 FSS. It was challenged in 2010 by *Kansas v. Nebraska* (2009-2015) and focused on both the FSS and the Compact, since the FSS is considered an extension of the Compact.

In the next section, I evaluate the FSS with the same factors and assessment questions (Table 5.3) that were used for the Compact assessment. Even though the FSS is directly tied to the Compact in that it describes annual virgin water accounting methods, each document is assessed separately because they developed during different circumstances and eras that deserve individual attention and discussion.

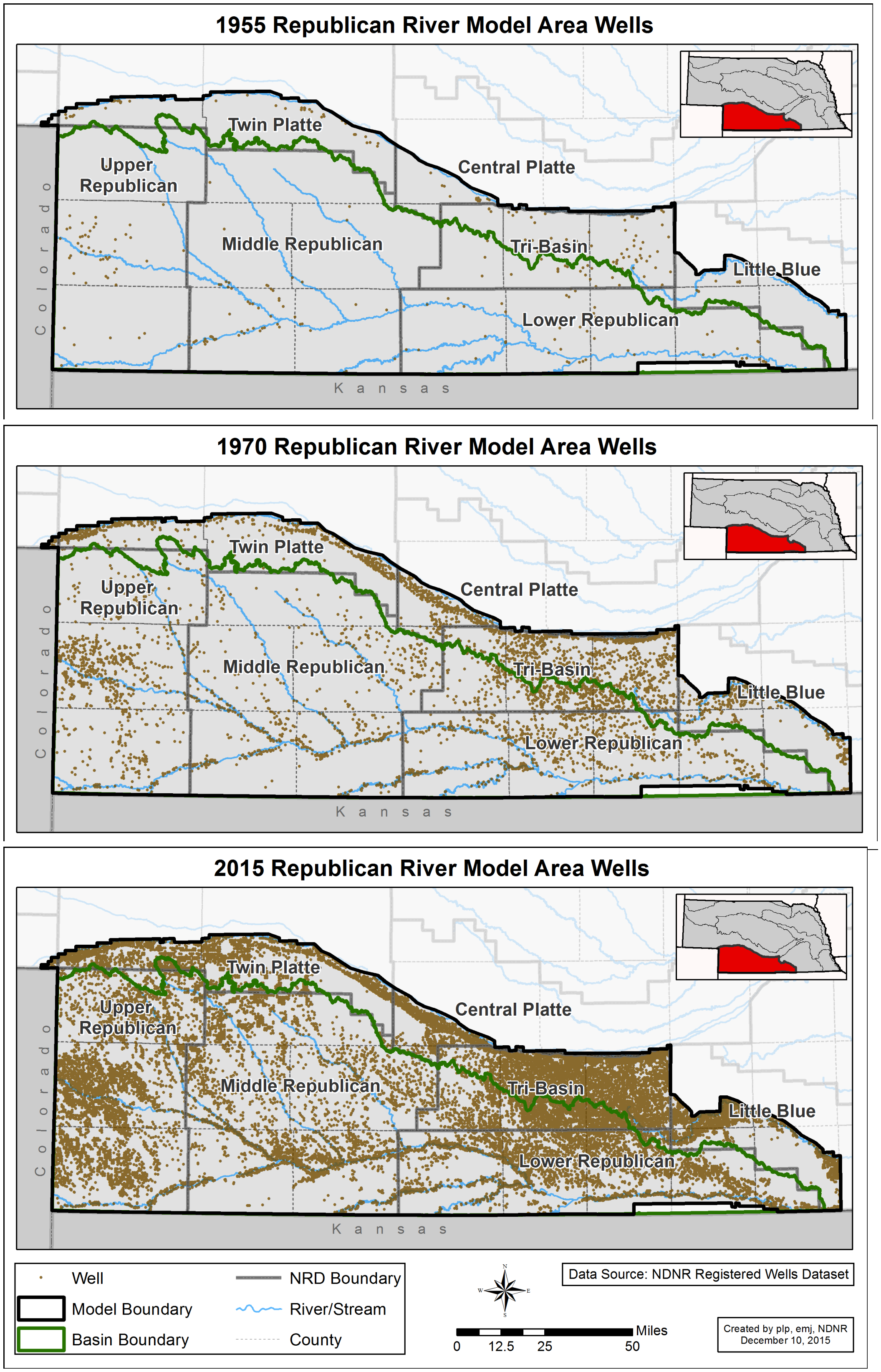


Figure 5.3. Nebraska's Republican River Basin Irrigation Wells. 1955 (top), 1970 (middle) and 2015 (bottom) (NDNR n.d.).

Final Settlement Stipulation Assessment Results and Discussion

The FSS's Low to Moderate overall score on my implementation assessment scale indicates improvement in some factor areas while at the same time retaining the need for more details. In general, the FSS improves upon and adds to the Compact's purpose of equitable division by being somewhat more specific, but does not fully address hierarchical integration or decision rules, for example, leaving open the need for more detailed language that will contribute to a better score and full statute success. Although the FSS addressed some of the issues associated with the 1998 lawsuit with the development and use of a groundwater model for measuring annual virgin water and state consumption, it was not successful in addressing all of them. In 2010 Kansas again filed suit against Nebraska, claiming that the state continued to negatively impact Kansas irrigators' Compact allocations during 2005 and 2006. Some of Kansas's frustration can be explained via the Compact and the FSS's language that allows Nebraska to continue groundwater pumping. The FSS's Subsection III Existing Development, Part B Exceptions to Moratorium on New Wells includes exceptions for N-CORPE and three NRDs that overlap the basin border along with small volume wells. What it does not do is reduce the number of groundwater wells or their volume in Nebraska's portion of the basin. It is left to the state to address. Sanctions are again completely missing from the document, there is no oversight except for the RRCA that does not have any real power, and the only effective recourse for violations is a federal lawsuit. A possible reason for the lack of enforcement provisions within interstate compacts could be state over-reach, whereby they use their power to interfere with another state's autonomy. Adopting compacts is one way for states to attempt to mitigate future litigation (Tyler 2003).

Achieving a better statutory and regulatory outcome for all the states is unknown at this time. It may come about from interstate collaboration or additional litigation.

Table 5.3 summarizes the ability of the FSS to structure implementation with a factor assessment score and representative examples. For clarity and consistency, the FSS significantly expands upon the Compact's goals and objectives (Table 5.2) in that there is a clear purpose with imposed deadlines. As a legally binding document, the FSS improves the states' abilities to meet Compact requirements and to some degree provides a template for the future. It does not preclude future conflicts that may result in litigation, particularly as legal, economic, and physical conditions change. Causal theory is also improved and indicates growth in regard to statute design as a way to both avoid and address potential problems. For example, the scope of defined terms is much broader and inclusive, but the FSS like the Compact, does not specifically identify the target group/s. To me it suggests a purposeful avoidance on the part of the states in order to preserve their power and internal decision-making. Either that, or they truly have not considered other basin actors and their role, either cooperatively or confrontationally with the Compact. Should water conditions decrease to the degree that an irrigation district like FCID or NBID is no longer viable, it leaves the door open for the state and other groups to use the state's water allocation for other purposes, since none of the irrigation districts are specifically named. However, politically and economically there would doubtless be conditions decrease to the degree that an irrigation district like FCID or NBID is no longer viable, it leaves the door open for the state and other groups to use the state's repercussion were they to do so. Whether or not this would violate the terms of the

Compact or related documents is not under review here. Rather, my purpose is to examine relevant possibilities as to the statutes success or failure.

Table 5.3. Republican River Final Settlement Stipulation Policy Implementation Assessment

STRUCTURE IMPLEMENTATION FACTORS AND SCORE	REPUBLICAN RIVER FINAL SETTLEMENT STIPULATION SPECIAL MASTER REPORT, 2002 STRUCTURAL IMPLEMENTATION EXAMPLES
1. CLARITY AND CONSISTENCY OF POLICY DIRECTIVES *MODERATE*	*Focused on pending litigation to limit groundwater use as it depletes surface flows (Kansas v. Nebraska and Colorado, No. 126, the Original)* • States agree to meet obligations of the Final Settlement Stipulation as scheduled; • Prior claims are generally waived and dismissed with prejudice; • States can continue to seek Compact enforcement; • The RRCA can modify accounting procedures consistent with Compact and FSS; • RRCA Groundwater Model provisions and enforcement are date and time constrained.
2A. CAUSAL THEORY: COGNITIVE — THE PROBLEM *MODERATE*	*Adequate but not comprehensive problem recognition* • 44 definitions such as computed and beneficial consumptive use, dewatering well, imported water supply, and unallocated supply; • time limits and guidelines are present; • target group(s) not clearly identified but assumed to be the States; • limited hydrological and geological data; • unaddressed complex jurisdictional authority; • limited non-statutory variable inclusion.
2B. CAUSAL THEORY: JURISDICTIONAL — ADEQUATE POWER *MODERATE*	*Reasonable jurisdictional control identified* • RRCA and States have greatest control; • Arbitrator has some control if RRCA and States cannot reach agreement; • U.S. Supreme Court maintains final authority.
3. FINANCIAL RESOURCES *LOW TO MODERATE*	*Limited initial and continuing costs and appropriations* • Arbitrator costs shared equally; • States and U.S. bear individual costs for legal and arbitration materials and preparation; • Non-Federal reservoirs and land terracing practices affecting water supplies study costs are defined and portioned between the U.S. and the States.

Table 5.3. (continued)

STRUCTURE IMPLEMENTATION FACTORS AND SCORE	REPUBLICAN RIVER FINAL SETTLEMENT STIPULATION SPECIAL MASTER REPORT, 2002 STRUCTURAL IMPLEMENTATION EXAMPLES
4A. HIERARCHICAL INTEGRATION: VETO POINTS *LOW*	*Multiple actor veto points* • Privileged material exempt from information sharing; • Any State may invoke binding arbitration, but requires other States' consent; • RRCA action must be unanimous; • States and their representatives can skip meetings to avoid dispute resolution through RRCA; • Disputes settled via RRCA arbitration are nonbinding; • Special Master can eliminate proposed arbitrators.
4B. HIERARCHICAL INTEGRATION: INCENTIVES AND SANCTIONS *LOW*	*No incentives* *Limited sanctions* • States can file lawsuits against other Compact States if the terms of the Compact are violated.
5. DECISION RULES *MODERATE*	Partial formal rules and guidelines • Each State submits an annual report for well constructi and denial upstream of Guide Rock; • RRCA accounting methodology will be used e.g., virgin water supply, allocations; • Groundwater modeling committee limited to not more than 3 state appointees per State; • U.S. may not designate more than 2 modeling committee members; • States share available data, information and expert knowledge and other for completing the model.
6. OFFICIALS' COMMITMENT *LOW TO MODERATE*	*Commitment largely rests with States and RRCA* • No specific recommendation for state administrative appointments or agency assignments; • Defers to Compact.
7. OUTSIDE ACCESS *LOW*	*Narrow access for outside actors* • Some non-members and State non-member representatives can attend, observe and participate at Modeling Committee meetings; • Modeling committee meetings and works subject to a confidentiality agreement between the States and the U.S..

Key: High = stronger asset for implementation; Moderate = reasonable asset with some potential problems; Low = unlikely asset with notable problems; Neutral = little impact on implementation.

Clarity, Consistency and Causal Theory

Perhaps most troubling and concerning for clarity and causal theory is that the FSS does not directly address *individual* well impacts or connectivity, the unaddressed jurisdictional authority, and limited reference to non-statutory variables such as socio-economic conditions or public support. Non-statutory variables can be the catalyst that underpins or undermines the forward momentum of a statute. Any one of those three omissions singly, let alone as a package, suggests several positions that the states have taken independently, as a group, overtly, or as a path of least resistance. My responses and interpretations to those omissions are discussed.

One, limited scope and focus: The States and U.S. did not want to be side-tracked or distracted from the FSS's purpose to neutralize Kansas's lawsuit (fewer Nebraska groundwater wells and a temporary River Master), and approach that neutralization with a narrow, limited focus and scope. The FSS allowed the States to find an expedient way to address declining surface flows with the Groundwater Model, but did not require Nebraska to shut down groundwater wells, thereby kicking the can down the road. While not an ideal solution from Kansas's perspective (they would prefer fewer wells), it forced Nebraska to acknowledge that their policies and practices had been detrimental to their Compact obligations.

Two, geological and hydrological profiles: The States and U.S. did not want to expend more time or money to build a thorough, comprehensive, accurate geological and hydrological profile of the interconnected surface and groundwater systems, thereby delaying the next legal challenge. In part it could be attributable to available technology and data along with financial costs in both time and money.

Additionally, it allows the Nebraska NRDs to continue to negatively impact hydrological connectivity in the basin. Nebraska groundwater advocates and their NRDs have significant political power that tempers legislative oversight action. One Nebraska manager commented that their district has already begun seeing groundwater levels creeping downward in their area as a direct result of an upstream district's groundwater pumping. It places them in a precarious position hydrologically, for setting seasonal irrigation water use limits, and meeting state expectations.

Three, legal challenges to individual well restrictions: The next legal challenge per number two above could come from an individual grower, irrigation district, or state claiming that the state, RRCA, or other entity can't prove that an individual well directly impacts surface flows. Therefore, an individual well should be exempt from well shut downs, rapid response well requirements, reduced pumping, or any other restriction. Undertaking such an endeavor is expensive and time consuming for all parties, there are likely physical impediments to mapping connections, data may be difficult to verify, and technological tools may be inadequate at the current time.

Four, databases and litigation: Failure to build comprehensive and tri-state wide hydrological and geological databases could mean future litigation. It will be important to have these databases because accurate and reliable data is critical for understanding water mining, surface flow impacts, climatic conditions, and potential geological change as a result of groundwater withdrawals. Additionally, ecosystems beyond the agriculture sector will be impacted, as will community water perceptions, and local and regional economic sustainability.

Five, states rights: Federalism and states' rights to internal decision-making and laws are primary to our governance system. When there is an adverse impact on Compact compliance, how a state chooses to balance their interstate obligations against their internal priorities is important, as those decisions might have ripple effects to the other states. If the RRCA were granted greater enforcement power that overrides a state's autonomy, or a Special River Master was permanently assigned oversight control of the Compact and the States' obligations, states' rights could be infringed upon. Neither of these options is without significant consequences.

Six, jurisdiction and NRDs: Currently, one of the largest and most pressing legal challenges to Compact and FSS success is Nebraska's unwillingness to directly limit and permanently reduce groundwater pumping in the NRDs. NRDs are independent from the NDNR even though they jointly develop water management plans (IMPs). During my interviews, at least one manager indicated that they would defer to their IMP rather than a legislatively required Republican River Basin-wide Plan that is under development with an early 2018 finalization (NDNR n.d.). There are insignificant political ramifications at the current time to incentivize NRDs to participate in the basin-wide plan, but legally they are required to complete and implement an IMP. However, it appears that IMPs are not enough because the NRDs aren't accountable to an oversight agency or official for their water usage decisions. It is difficult for NRD boards to limit themselves and their neighbors, since some of them are resource maximizers in contrast to those who want to maintain or reduce pumping levels to prolong irrigation practices into at least the foreseeable future. In interviews with basin stakeholders, it was not uncommon for irrigation boards and managers to share their reluctance to make hard choices about limiting water and shutting down irrigation wells. Thus, how can a balance be achieved between NRDs, the state, and the Compact, since it is a matter of resource use beliefs and perceptions. Obviously, it is a constitutional issue as well, but nonetheless, the problem continues, causing problems for FCID, NBID and to a lesser extent Kansas Bostwick Irrigation District (KBID).

Seven, non-statutory variables: There is limited or missing acknowledgement of non-statutory variables such as socio-economic conditions and leadership support at the state and regional levels, especially when no crisis exists. These are both necessary to avoid and minimize future crises. Continuous support and leadership is essential to maintaining a litigation-free Compact especially when it is a wet year or period as opposed to a drought event. An array of socio-economic conditions can be highly variable and influence success like agricultural commodities and subsidies, rural depopulation, trade agreements, crop insurance, and technological costs. Further, climatic change will likely impact all sectors and elements. Just as important are individual personal experiences that color water perceptions and behaviors.

While recognizing the intricacy of managing water across boundaries and the desire to have some local or regional flexibility, Compact framers risk being too ambiguous and unspecific thereby leading to local and regional operational uncertainty and potentially costly litigation. Failure to address these important compact elements can put the states in a static box due to uncertainty. Schlager and Heikkila (2009) reported that although compacts can be seen as rigid and inflexible, conflict resolution by commissions can be effective by revising rules; the RRCA functions in this manner. Further, they report that other conflicts will need litigation to address entrenched differences between up- and down-stream states and multi-issue concerns about distribution, models, and water quality. Incentives that encourage the diffusion of ideas to minimize risk and increase cooperation need to be included, along with sanctions that are unattractive politically and financially to the states such as fixed penalties. Three examples suffice.

First, Fowler and Castellano (2017) found that multiple sources and institutional layers can assist with accountability, enforcement, and reporting for compact infractions. Second, Draper (2007) offers organizational design principles that are focused on administrative and institutional provisions of governance. Although suggested for new compact design, they can be adapted for current compacts. Finally, McNeal (2015) suggests a five-factor test for compact breaches and degrees of disgorgement for the state that breaks compact rules. Both Draper and McNeal reference the Republican River Compact specifically. Draper does so as an interstate compact with no initial active administration: "It shall be the duty of the three States to administer this compact through the official in each State who is now or may hereafter be charged" (Article IX). McNeal uses it as a case study to illustrate the need for adherence incentives to avoid costly litigation and potentially damaging disgorgement. These and other methods deserve serious consideration in compact design and language to assist implementation.

As interstate compact negotiations have matured and evolved through time, new ones tend to avoid the pitfalls of the early and mid-20th century. McCormick (1994) offers several suggestions for transboundary water allocation compacts based on an analysis of 22 Western compacts. These include percentage allocations, minimum flows, dispute resolution mechanisms, a comprehensive scope that includes groundwater, addressing federal claims, and federal policy protections. None of these options are without counterclaims, for example, what strategies are used during dry years to share in declines or how prior appropriation is represented. Of these 22 compacts, with ratification or amendments ranging from 1922 to 1992, 12 have no dispute mechanism, three have some type of arbitration, and the remaining seven compacts employ voting systems. As to allocating water, other than one that has no method, six use a percentage method, and the rest have storage limitations, fixed quantities, priority rights, and other means that address the shared waters.

McCormick (1994) contrasts these compacts with the 1961 Delaware River Basin Compact that has empowered its compact commission to allocate water between the states and approve or deny in-state water projects that affect the Delaware River. Furthermore, the Delaware action was the first compact that ratified a regional administrative body that foregrounded the river basin itself as the most significant actor by giving management and enforcement powers to a commission that could disregard political boundaries (Delaware River Basin Commission 2017). It is in marked contrast to most of these western compacts that were devised at an earlier time, under different environmental conditions, and have a different view of property rights. Although McCormick's work focused on select elements, it illustrates the need for a comprehensive approach to *all* the variables and factors identified by Mazmanian and Sabatier that are necessary for successful statute implementation.

Financial Resources

Financial resources for the FSS and its associated model are adequately divided and assigned to the states and others as envisioned to meet included time constraints. It does not address continuing needs such as costs associated with model upgrades or physical surveys that could add to model accuracy. The FSS is more specific than the original Compact document that made no financial references, as if money was not, nor would be, a factor in ongoing compliance between the states. Not included in the FSS are litigation costs; they are assumed to be the responsibility of the states.

Hierarchical Integration

Hierarchical Integration still delays addressing veto points. Individual states maintain their power to check other Compact states especially if the other's actions are seen as harmful to them. Failure to address veto points goes to the lack of cooperative and collaborative incentives rather than the stick — a lawsuit. Arbitration in the FSS simply requires the consent of the other state/s to engage in the process, and the arbitration ruling is not binding. One possible incentive to engage in arbitration is to negotiate solutions outside the courts, but that was not a successful strategy for Nebraska after their water overuse in 2005 and 2006. Their inability to reach an amenable solution with Kansas directly led to 2010's *Kansas v. Nebraska* and Nebraska's financial disbursement of $5.5 million dollars in addition to paying their own legal fees (Griggs 2017). A state could choose not to participate and avoid any potential consequences, despite being required by RRCA rules to report annual water usage. Furthermore, because the arbitration is not binding, states can disregard the findings, and risk later litigation while in the meantime continue to breach the Compact. What state will choose binding arbitration if it did not have to, and does anyone have the power to force the choice upon them? Not the RRCA, they do not have a stick. Possibly the Supreme Court, but their stick can have unexpected consequences for all parties. How arbitration might impact a State's future compliance or prevent states from future action is completely unpredictable. One could argue that it is in the best interest for the states to work towards a common goal, since the tri-state basin is a reality that cannot be denied, but rationality and self-interest are often paramount. Such a solution would be difficult to achieve because no state will willingly give up power to another State or actor because it is not in the state's interest to do so, or at least at the present time and current environmental and political conditions. A Supreme Court case is time consuming and expensive, which might cause a state to consider a limited alternative. However, the hierarchical integration is likely to remain low since it protects states' rights through veto points, but there could be improvements in incentives and sanctions that might make more palliative a higher degree of

DECISION RULES, COMMITMENT, ACCESS

With Decision Rules the number of model appointees, methodology, and reporting requirements are reasonable and representative of the number of states. By limiting the number of people for model development and state representation, the model was more likely to succeed particularly with technical and hydrological expertise from representatives. RRCA water accounting methods fall under the same auspices. States and the RRCA approve water use with a post-accounting method that gives states time to collect accurate seasonal data as well as averaging water use over a period of years depending on conditions. Typically they approve water use at the annual RRCA meeting, for example, 2016 usage was approved in late summer or early fall 2017. Given these and related conditions, this statute implementation variable seems likely to succeed.

Generally an officials' commitment is dependent on a number of motives and factors, such as bureaucratic structures, politics, and funding. If there is strong commitment to the statute and its ideal, Mazmanian and Sabatier project the time commitment to be at least 7 years for full implantation and likely closer to 10.

During the 1998-2016 period Nebraska had seven DNR directors or acting directors (Mike Jess, Roger Patterson, Brian Dunnigan, Don Blankenau, Ann Bleed, James Schneider, and Jeff Fassett) and two Supreme Court Compact lawsuits filed against them. State lawsuits are not included, and they are numerous. During the same period, two retirements took place between the four Nebraska NRDs and three irrigation districts, one at the Middle Republican River NRD and the other at Kansas Bostwick. Since 2004, when Colorado created the Republican River Water Conservation District it has had the same general manager. Both Kansas and Colorado have each gotten one new state engineer. These situations illustrate the difficulty of maintaining administrative consistency over time and the likelihood of successful statute implementation longevity especially in Nebraska.

Each federal legal action needed or resulted in some degree of cooperation and implementation among Nebraska actors. Nebraska DNR manages surface water, is directly involved with basin decision-making, and is tasked with making sure state allocation limits are not exceeded. At the largest scale, the states and the RRCA have a high degree of commitment, but it may not be the same at other bureaucratic levels. Thus, overall commitment remains in flux. Another important component is the professional working environments and the influence they can have on administrative and Compact relationships.

As to Access, those outside the select modeling group have limited access to its meetings and materials. If someone is part of a state's hierarchy, they may be able to observe at meetings, but not directly contribute at that time. Instead, it may occur behind the scenes. If a member of the general public such as an irrigation district member wished to observe or gain access to the committee's work, they are barred from doing so because of confidentiality agreements. One interpretation could be that an irrigator or basin stakeholder would be denied access to the process because they aren't officially recognized as a member, yet the work being undertaken will directly impact the irrigation district and the grower's agricultural operations at a future point. Lack of access makes it very difficult to question or accuse the RRCA, or the states for that matter, of inaccuracies or wrong doings. Citizens and growers are dependent on publically available data that may be incomplete. If a lawsuit were filed to access all materials, the public would first need to prove that they have standing to file the suit, a legal bar that has at times proven difficult to overcome.

The groundwater model has been available to the public since 2006, but some information such as soil classification remains under a confidentiality agreement (David Barfield, Kansas Chief Engineer, pers. comm. 2016). As a researcher, I was unable to receive information about how the Compact's model had set parameters for soil type and water holding capacity to use in my streamflow analysis comparisons. Inaccessible data restricts the opportunity to verify or compare Compact results with other methods. The need to limit access during development is understandable given the technical and legal ramifications of the work. However, best practices, perceptions, and local buy-in might be more readily achieved when affected stakeholders are consulted and updated to ensure their understanding and continued support. I propose that transparency matters in implementation, an area that Mazmanian and Sabatier do not address directly. Without transparency, distrust and litigation are outcomes that are costly impediments to solving water conflicts in the basin.

Assessment Discussion and Conclusion

Implementation studies analyze statute and policy initiatives and their ability to successfully achieve their goals and objectives. In the case of the Compact and FSS each is attempting to regulate behavior like allocation compliance, rather than a specific service like infrastructure. My assessment emphasizes program performance based on the statutes' objectives and the extent to whether they did or did not address problems and solutions, rather than outputs like agency regulations and outcomes like equitable water. Any assessment in essence is an examination of public policy and administrative performance (Mazmanian and Sabatier 1981). For the Compact and FSS this means that the states are obligated with implementation via internal action and power, some of which is undertaken in conjunction with the RRCA. Once written and approved, any statute's oversight by Congress or state legislatures becomes much less trendy as the spotlight shifts to other crises or pet projects. In the Republican River basin, officials are elected and appointed. Elected officials include state legislators and irrigation board members, while appointed officials are irrigation district managers and state agency directors. Each group has different priorities that color their attention and support for Compact oversight. Oversight then has a spectrum depending on immediacy. The basin growers and irrigation districts lavish the most oversight attention because if it does not work they will bear its socio-economic costs directly, as opposed to the other actors who have increasingly more programs to monitor and oversee and are not directly or economically tied to its success, unless there is a pending lawsuit.

It could be argued to some extent that the Compact and FSS have achieved their objectives, but the opposite equally could be said (Table 5.4). Impacts such as water usage limits are uneven across the basin, and technology is under considered. It in turn has led to stakeholder frustration and ennui regarding actual beneficial implementation. The angst experienced by the basin's growers can be explained by a brief discussion of the three different perspectives that are important for implementation — the center, periphery, and target group (Mazmanian and Sabatier 1981).

The center, the periphery, and target group each has different expectations and views. The center as the initial policy maker (here some combination of the U.S., states, and RRCA) is most focused on whether or not, and how, the Compact and FSS objectives have been met. They need to ensure that policy compliance takes place with the periphery and other actors in the form of service provisions like accounting protocols, or changed target group behaviors like using less water. The periphery is akin to field-level officials, such as local and state agency bureaucrats, and behavioral responses to the disruption a new outside policy (from the center) presents to them. In other words, how can or will the periphery achieve the new policy objectives and goals in light of current obligations. State agencies, such as the

Kansas Department of Agriculture, which includes the Division of Water Resources, are responsible for a vast number of local, state, and federal policies, so any new initiative like the FSS or model may strain current resources in time, employees, and costs. How they re-adjust and prioritize a new policy among other equal value priorities becomes paramount. Obviously, it is an administrative and managerial issue best discussed elsewhere.

Table 5.4. Compact and FSS Summary: Conditions of Effective Implementation

	Condition	Compact	FSS
Statutory Structure	Clarity and Consistency of Policy Directives	Low	Moderate
	Causal Cognitive and Jurisdictional Theory	Low	Moderate
	Structures Implementation Process (5)	Low	Moderate
Non-Statutory Variable	Officials' Commitment and Skill	Low	Low to Moderate
	Continued Support	Low	Low to Moderate
	Socio-Economic and Technical Conditions	Low	Low to Moderate

Key
High = stronger asset in effective implementation of legal objective
Moderate = conducive to effective implementation, although some problems
Low = notable obstacles to effective implementation
Neutral = factor played little or no role in implementation role
(Mazmanian and Sabatier 1989)

Private actors most commonly make up the target group. If they will benefit from the statute's goals, their perspective will be similar to the center's views as long as policy outcomes and services are delivered (Schneider and Ingram 1993), such as whether or not the model accurately represents reality. However, those services have to make a positive difference for the basin's growers. For the FSS, it may be debatable given that the model has provided more detailed and accurate hydrological data than the Compact included, but neither have been able to ensure reliable water for the irrigation districts and their members in either short- or long-term scenarios. With the states' ability to use 2- and 5-year water averages to meet water needs, they may argue differently than the irrigation districts. In particular, groundwater pumping, crop type, precipitation, and climate change impact water allocations on a yearly basis. If the NDNR determines whether or not a Compact Call Year goes into effect, at which point surface water appropriations are closed, it means Frenchman-Cambridge and Nebraska Bostwick irrigators don't receive any water, it is stored or sent to Kansas. In 2017, Nebraska issued its 5th year-in-a-row Compact Call (NDNR 2016; *McCook Gazette* 2017). The two documents' language and structure falls short of meeting this target group's needs. Additionally, neither document calls for formal evaluation studies other than the required annual accounting; cooperative RRCA actions are voluntary.

A consensus exists of sorts between each group's perspectives because the Compact binds them together — we have to be compliant. However, the target group can assert that their best interests are not being met because of vague language, differing interpretations between them and the periphery, and little to no input for policy outcomes, while the periphery can argue that they are constrained by state statutes, most prominently water laws. Conflict arises first at the local level, move upward internally at the state level, onto the RRCA, and then the U.S., all highlighting the inadequacies for both the Compact and the FSS.

Possible solutions to basin conflicts include a temporary or permanent River Master (rejected by the 2015 Special Master), or a basin commission in the image of the Delaware Commission where representatives have one vote and the majority rules (Delaware River Basin Commission 2017), or some other independent entity. If the states either voluntarily or forcibly take one of these paths, jurisdictional power to level consequences or impose sanctions upon the States will be necessary. Such a path seems unlikely at the current time due to states' rights, local attitudes towards regulation, a desire for local control, and historical perceptions surrounding water. Consensus between states to solve and address current and future potential problems (as noted above) through the RRCA has been a partial solution, as with the FSS and other agreements. Unless states agree to independent oversight, binding arbitration or some other legal resolution, conflicts and litigation at all scales will likely continue.

Utilizing Mazmanian and Sabatier's policy implementation analysis methodology, specifically its structural implementation factors, led me to conclude unsurprisingly that while the language, goals, and objectives have improved since the original Compact was ratified and put into place, the FSS is an incomplete document even as it improves and clarifies the Compact. It allows states to continue to leverage their power against each other rather than working towards a common basin wide solution for the irrigators and waters of the basin. Furthermore, I suggest that Mazmanian and Sabatier's policy implementation framework should consider adding transparency of purpose, development, and implementation as a factor to its statute structural implementation independent variable. Transparency can assist in addressing target group concerns, garnering additional data, recruiting supporters, and adding clarity to frequently murky processes, thereby avoiding unnecessary challenges.

I began with two overarching questions as asked by Mazmanian and Sabatier (1981, 1989). First, are the statutes and agreements service or behavior oriented and second, do they attain their objectives. The legal documents are regulating a specific type of behavior, broadly, Compact compliance through the efficient and beneficial use of the waters equitably allocated to them from the Republican River. As has been demonstrated here and elsewhere, the upstream states of Colorado and Nebraska especially have struggled to stay within their equitable allotment at various points in time. Because they have not been able to regulate their behavior to the satisfaction of Kansas under Compact or FSS conditions, they were federally sued, twice. Regulating behavior for water is difficult and some of those pitfalls and gaps have been highlighted in the assessments. Second, the legal documents do not fully attain their objectives of efficiently and beneficially using the water allocated to them and avoiding controversies. The Compact in its original form is poorly conceived and executed for a variety of reasons already discussed. The FSS addressed some of those overlooked relational causes with the development of a groundwater model, but jurisdictional oversight remains opaque. From the perspective of the states and the irrigation districts, the FSS has made strides towards better guidance versus the Compact. They also acknowledge that the FSS is not perfect and may never be so, while also hoping for less litigation.

Both legal documents are rife with ambiguity, although less so with the FSS than the Compact, which has little chance of every being changed. It is then left to the States, the RRCA, the Supreme Court, and state district courts to resolve future conflicts whether through direct litigation or other means. No two compacts will be the same because the conditions under which they derive are unique to their time, place, and space. However, lessons, practices, means, and solutions can be garnered from other compacts, their challenges, and their decisions. The Republican River states would be wise to pro-actively attend “to remove all causes, present and future, which might lead to controversies” (Article I).

Chapter 6
Republican River Streamflow Scenarios

The Republican River Compact is centered on two basic ideas: one, to discourage conflict between the states over the river's water, and two, to share that water equitably. Neither of those two goals has been without challenges. The Compact has been challenged twice by Kansas in lawsuits against Colorado and Nebraska for overuse of the water, thereby depriving Kansas of their legal share and causing harm to their irrigators at KBID. While equitable allocation of the river's water divides its virgin water (surface and groundwater), "water supply within the Basin undepleted by the activities of man" (Article II), the Compact did not foresee how people and climatic events would vastly change the waterscape of the basin. The advent of submersible pumps and center pivot irrigation systems in the late 1950s in conjunction with periodic drought clusters (mid-1950s, late 1970s and 80s, early 1990s and 2000s) (Wilhite 2011) and climate change have shifted power away from surface water irrigators to groundwater irrigators, from a river with adequate surface flows under normal climate conditions at the time of the Compact to one that can have no visible surface flows and decreased base flows.

The river as an ecosystem service (ESS) is changing, and so too as part of the region's larger socio-ecological system (SES). Residents of the basin rely on its water; their relationship with it is a symbiotic one. Their use and management decisions impact the river and themselves, so how goes the river, goes their growing season, income, schools, and communities. Whether the water is accessed as surface or groundwater makes a difference. Those who have surface water rights do not experience the same water reliability as those with groundwater rights, and some parts of the basin have no access to groundwater at all. Under these conditions, it is important to understand the socio-hydrological relationships that define the basin and to analyze its elements. I present streamflow scenarios as a component of my socio-hydrological profile.

With 2.7 million irrigated surface and groundwater acres in the basin (1.6 million in Nebraska, 435,000 in Kansas, and 550,000 in Colorado) (Brookfield and Wilson 2015), knowing how much growing season water is available to irrigation districts for surface water irrigation is important. Irrigated Nebraska acreages of the basin generate nearly $35 million in tax revenue that support local governance and infrastructure (Your NRD Basin: Republican River 2015). Under simulated natural (unmanaged) and managed conditions, annual streamflow data is analyzed to reveal society's role in the Republican River system, its socio-hydrology. I explore how decision-making and Compact allocations could be met or have been met under those conditions with three data sources and two models. I am guided by two questions. One, how are management decisions presented in the instrumental record? In particular, what management decisions are evident (and which are not) from observational records? Two, can simple models provide additional mechanistic insight into the observed streamflow dynamics?

The chapter addresses sources for observational and instrumental data acquisition, the models and methods used with the data to develop streamflow scenarios, the model results as time series, and a discussion of model effectiveness and Compact implications relative to the basin's socio-hydrological profile.

Observational and Instrumental Data Sources

Data were gathered for an upper and lower basin site from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information Cooperative Observer Network (COOP) for hydro-meteorological data, the United States Geological Survey (USGS) stream gauge network, and the Republican River Compact Administration's (RRCA) groundwater model. Sources report weather and streamflow data in daily, monthly, or annual periods. Longevity and completeness of record was of primary importance.

COOP Daily Weather Data

For the upper basin location, I use St. Francis, Cheyenne County, Kansas and for the lower basin location, Red Cloud, Webster County, Nebraska (hereafter St. Francis or Red Cloud, respectively). With daily hydro-meteorological (precipitation and temperature) input from the instrumental record, I constructed climatic trends for temperature, precipitation, and streamflow with a water balance model. Red Cloud and St. Francis were selected as representative of the basin's climatic and physical conditions, along with length and completeness of daily weather records (Table 6.1 and Figure 6.1). Required input variables for the water-balance model are daily high (Tmax) and low (Tmin) temperatures and total daily precipitation (Precip).

St. Francis and Red Cloud's hydro-meteorological data was sourced from the COOP network and the High Plains Regional Climate Center (HPRCC), who use COOP data for research, monitoring, and other services. COOP data is a primary data source for U.S. climate analysis with an extensive observer network for over 100 years (Kunkel et al. 2013). Missing COOP data points are filled by HPRCC using a weighted average of the nearest five stations (HPRCC 2015). Similar techniques are a common practice among climatologists and modelers (Jeffrey et al. 2001; Wang et al. 2012).

Table 6.1. Cooperative Weather Stations and USGS Stream Gauges

State	*County*	*COOP ID; Latitude & Longitude*	*Elev. m (ft)*	*Years of Record*
COOP Nebraska	Webster	*Red Cloud* USC00257070 N 40.0977 W 98.5197	524.3 (1732)	1901-present
Kansas	Cheyenne	*St. Francis* USC00147093 N 39.7675 W 101.8066	1024.7 (3362)	1908-present
USGS Kansas	Republic	*Near Hardy, NE* USGS 06853500 N 39.99 W 97.93	457.65 (1501.46)	1957-present
Nebraska	Dundy	*Near Benkelman* USGS 06827500 N 40.00 W 101.54	911.32 (2989.9)	1937-present

(High Plains Regional Climate Center Station Tool 2017; USGS National Water Information System 2017a.)

St. Francis, located on the South Fork of the Republican River in the upper western half of the basin, represents the basin's semi-arid conditions. Red Cloud, on the main stem and at the lower eastern end of the basin, is less arid, and closer to a Great Plains semi-humid climatic zone. In Nebraska and Kansas, precipitation increases to the east around 5 cm (or 2 inches) for about every half-degree change in longitude (Kansas State University n.d.; UNL Water 2017; Prism Climate Group 2017). Colorado's portion of the basin is similar in temperature and precipitation to western Nebraska and Kansas (WRCC 2016).

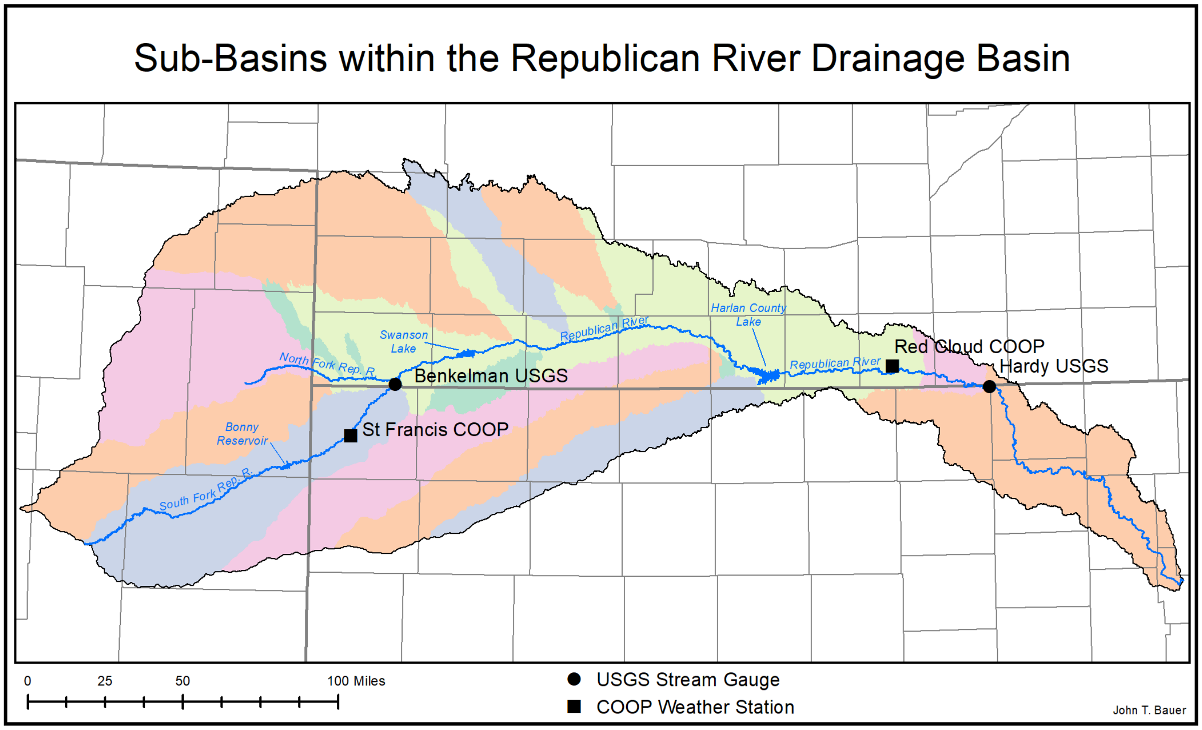


Figure 6.1. Republican River Basin: Sub-Basins and Data Sites. USGS and COOP sites in the western South Fork sub-basin and Hardy and in the eastern main stem (Bauer 2017).

<u>USGS Data</u>

The USGS stream gauge data was acquired from the *National Water Information System* web page (USGS 2017a). It allows users to select their gauge site as well as the time series and variable or statistics such as discharge, gauge height, or sediment concentration. Gauges were selected based on their proximity to the COOP weather stations and record length. I use the annual (calendar year) time series for streamflow for each of the two basin locations. The USGS has two drainage basin options; I use the regular area drainage area option (area above the gauge). The USGS gauge data represents a managed streamflow scenario.

The USGS Benkelman, Dundy County, Nebraska gauge (hereafter Benkelman) on the Republican River's South Fork was selected to pair with the nearby St. Francis COOP weather station (Table 6.1); the site is also near its confluence with the main stem Republican River. As a sub-basin, it allows for smaller areal comparisons that may more readily show water management decisions especially because it is downstream from Bonny Reservoir and is in the more arid western region (Figure 6.1). At the present time (2017), no federal Colorado or Kansas irrigation districts in this sub-basin use the river's surface water.

The USGS gauge near Hardy, Nuckolls County, Nebraska (hereafter Hardy) was selected as a match for Red Cloud's COOP weather site based on drainage area size, length of record, and location to the COOP station. The Hardy site is adjacent to the state border between Kansas and Nebraska.

RRCA DATA

Through an open records request made to the Kansas Department of Agriculture, Division of Water Resources (KDWR), I received RRCA base flow stream calculations from 1918-2015 for both pre- (no irrigation) and post-development (irrigation) conditions for the upstream Benkelman and downstream Hardy location (Appendix B). Base flow is a fraction of streamflow that originates with groundwater, while streamflow includes base, surface, and groundwater flow among other components. The RRCA groundwater model is a modified version of USGS's MODFLOW and simulates base flow conditions (RRCA n.d.a.). MODFLOW is a modular hydrologic model used to simulate and predict various water interactions including surface water-groundwater relationships and groundwater conditions (USGS 2017b). The RRCA uses the finite-difference version of MODFLOW (RRCA n.d.a.) and as such would not be considered a traditional water budget model that is focused on conservation of mass.

Models and Methods

Water balance models are highly idealized representations of processes such as precipitation and evapotranspiration that govern the exchange of water across the land–atmosphere interface. These water balance models are fundamentally local and do not explicitly account for horizontal transports of water. Despite their simplicity, water balance models are useful to help identify conditions of water availability and stress, such as lack of soil water for cultivated and irrigated crops, the risk of fire, groundwater recharge, soil degradation, and possible impacts to different climate-change scenarios (Mather 1979; Sophocleous 1991; Feddema 1998; Maxwell and Condon 2016; Mackenzie and Littell 2017; Rolim et al. 2017).

I use two models, a water bucket balance model (WB) with the COOP hydro-meteorological data, and the RRCA's groundwater model (Model) to undertake an analysis of how streamflow in the basin differs by data source and location. The RRCA model is more complex, but both can be considered low-dimensional models since they are being applied to a relatively localized, finite area, the river basin, over a specified time. The RRCA model is designed specifically for the Republican River basin, and even though WBs aren't typically applied as I am using it here, it still provides useful information.

WATER BALANCE BUCKET MODEL

Water balance calculations came from a water balance model written in Excel by Feddema (n.d.). A water bucket model assumes that a bucket fills by precipitation and empties by evaporation much like a rain barrel or stock tank left out in a treeless field. A full bucket means there is extra water for deeper water drainage into soils and aquifers, an empty bucket implies no water for plants, animals, or subsurface water recharge. The bucket model required three inputs: daily high temperature (Tmax), daily low temperature (Tmin), and daily total precipitation (Precip). Using those inputs, it calculated potential annual basin streamflow, among other possible outputs. Mather's *The Climatic Water Budget in Environmental Analysis* (1978) guided parameter settings, for example, soil water holding capacity (Table 6.2). I choose Thornthwaite's evapotranspiration method because it is based on a watershed and can be applied in irrigated settings (Thornthwaite 1948; Thornthwaite and Mather 1955), as well as being well tested and frequently used for water resources studies (see Ward 1972; Feddema 1998; Singh et al. 2004; Sridhar et al. 2006; Sridhar and Hubbard 2009). I used the full basin size for the water bucket scenarios, and readily acknowledge the inherent problems of doing so, mainly, assuming even precipitation distribution throughout the basin.

Table 6.2. Major Water Input and Parameter Settings

VARIABLE	*SETTING*
Evapotranspiration	Thornthwaite Method
Water Holding Capacity	133 mm
Growing Degree Days	180
Run-Off	On (for overland and infiltrated water)
Location	COOP weather station latitude
Growing Season start/end	Day 122 (May 5) to Day 300 (October 26)
Temperature	Daily Tmax and Tmin ^{o}C
Precipitation	Daily total mm
Drainage Area*	Basin: 64490 km^2; USGS Benkelman: 7097 km^2; USGS Hardy: 58,018 km^2.

*Some water balance scenarios were matched to USGS drainage areas (Mather 1978).

RRCA GROUNDWATER MODEL

The RRCA Groundwater Model was developed as part of the 2002 Supreme Court Final Settlement Stipulation to identify and address streamflow depletions in the river and imported water accretions in the basin (FSS 2002). Conceptually and mathematically it includes recharge sources, irrigated acres, streams, reservoirs, and other variables that contribute to the amount, location, and timing of the river's water and the states' use of water (FSS 2002).

The Model simulates calculations for base flows under one of two conditions: pre-development and post-development. Pre-development conditions mean that irrigation is turned off in the model, "All Off." Post-development conditions have irrigation turned on, "All On" or historical conditions. The post-development option includes groundwater pumping and irrigation return flow, for example; Appendix B includes the model conditions. In this way, the Model can calculate each state's respective impact on the stream because it can be set to turn on or off each state's irrigation impacts (FSS 2002). The “All On” historical conditions represent managed streamflow relative to irrigation activity. “All Off” is equivalent to the water bucket model streamflow calculation for natural or unmanaged streamflow.

There are three additional points about the Model’s application to my research question. I acquired output data from two locations or segments, the South Fork of the Republican River and the main stem at Hardy. An RRCA schematic illustrates specific model segments in Appendix B. Two, the Model’s simulation is for base flow; both the WB and USGS show surface flows. Three, due to the hydrology of the basin and negotiations between the states, the Model uses a larger drainage area than does either the WB or the USGS. In this instance, I am more interested in the patterns and trends, rather than a comparison of absolute flow rates, although these are certainly a consideration for meeting the Compact requirements.

METHODS

I took several steps with the acquired data to illustrate climatic and streamflow trends for the upper (west) and lower (east) basin locations in order to discuss management strategies and Compact compliance. I also did analysis at two scales, the full basin and a sub-basin, the South Fork. At this smaller scale, streamflow differences between sources could be more apparent if they exist. Further, water in Bonny Reservoir on the South Fork has been stored for Compact use, so water releases could show up on the USGS gauge and in the RRCA data.

First, I designated the WB output streamflow data as one of three scenarios, dry (west), wet (east), or hybrid. The dry scenario is equivalent to the St. Francis data, the wet scenario is identified with the Red Cloud data, and the hybrid scenario was a weighted average (two-thirds St. Francis (west) data and one-third Red Cloud (east) data). As most of the basin lies west of the 100th meridian (Figure 6.2), a frequent marker for the 20” (50 cm) isohyet and some row crop water needs, it was a reasonable apportionment to represent the differing annual precipitation totals within the basin. The hybrid’s weighted average offered another opportunity to simulate possible basin streamflow.

Second, for all three data sources as independent sites, I computed and plotted streamflow centered running means for 5- and 29-year periods. A five-year mean is centered on year three plus the two previous and two following years; likewise for 29-year periods centered on year 15.

Third, to assess trends and identify management decisions in streamflow patterns, I made comparisons across locations with each source (USGS Benkelman and USGS Hardy) and between sources for the nearby location (WB St. Francis and USGS Benkelman). Since the RRCA uses USGS stream gauge data, I expect similarities in their streamflow patterns and trends.

Time series results are presented next. I start with WB hydro-meteorological data at St. Francis and Red Cloud for a general overview of the region and basin. Temperature and precipitation anomalies based on the 1981-2010 climate normal period for St. Francis and Red Cloud are found in Appendix B. The remainder of the results section is focused on streamflow.

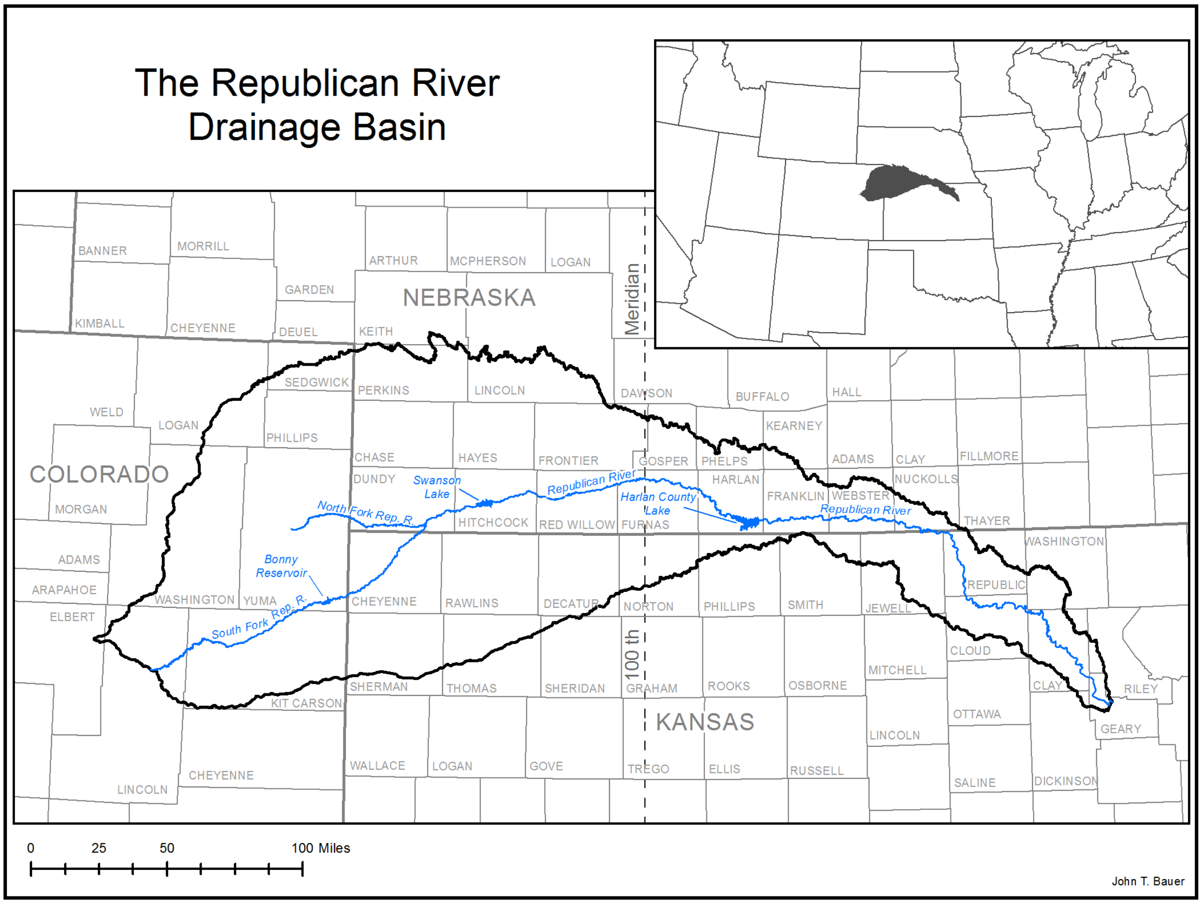


Figure 6.2. The Republican River Basin with the 100th meridian. (Bauer 2017)

Time Series Results

Hydro-Meteorological Data

Annual temperature means from 1909-2015 between St. Francis and Red Cloud are nearly the same, as is their range, highs and lows (Table 6.3). Precipitation is a bit more diverse for its descriptive statistics. On average, St. Francis receives about 25% less precipitation than Red Cloud, so there could be a greater impact on surface flows and the need for supplemental water, irrigation, in that western region of the basin. For the Great Plains (1981-2010), past annual average temperature ranges from 51-55°F and precipitation west to east is 16-30” (Kunkel et al. 2013; NCA 2014).

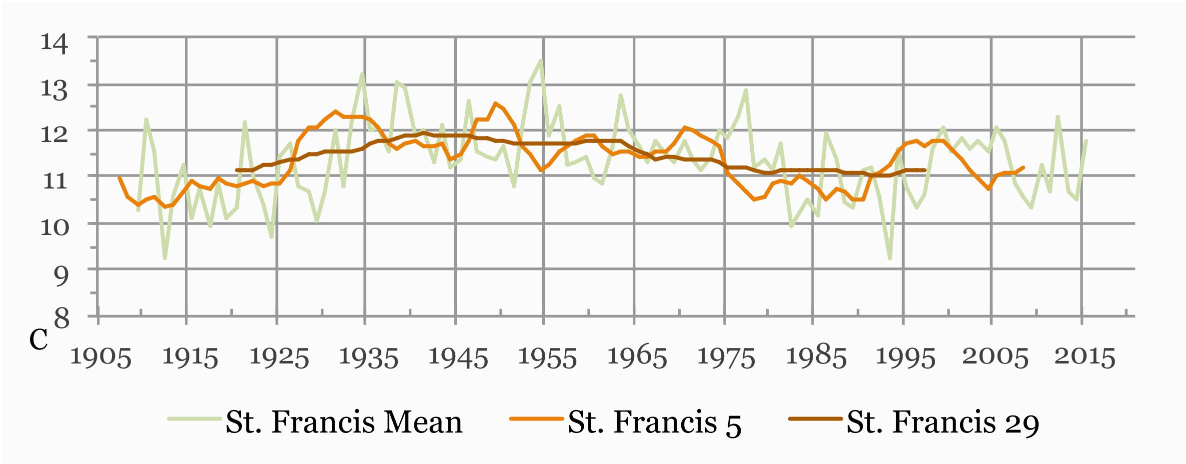
Table 6.3. Historical Annual Precipitation and Temperature Means, Red Cloud, Nebraska and St. Francis, Kansas.

		Red Cloud, Nebraska		*St. Francis, Kansas*	
Temperature (°C)	High	13.7	(1934)	13.5	(1954)
	Low	8.7	(1993)	9.2	(1993)
	Range	5	(~25°F)	4.7	(~24°F)
	Average	11	(~52°F)	11.3	(~52°F)
Precipitation (mm)	High	1,026.9	(1973)	595.9	(1920)
	Low	303.8	(1934)	254.2	(1954)
	Range	723.1	(~30")	371.7	(~15")
	Average	625.6	(~25")	470.7	(~19")

(NOAA COOP n.d.a.)

Running means for temperatures at each location are displayed in Figure 6.3. Based on the 29-year mean, temperatures show a slight downward trend for this time period from annual high mean temperatures around 12°C during the mid-20th century to somewhere around 10°C in the early 21st century. Climate change predictions by the North American Regional Climate Change Assessment Program (Mearns et al. 2012) project an increase of temperature and a shift in precipitation, impacting evaporation rates, crop water needs and surface water flows (IPCC 2007, 2013, 2014; Mearns et al. 2012; Mearns et al. 2013; Melillo et al. 2014).

Plotting mean precipitation trends for St. Francis and Red Cloud (Figure 6.4) paints a picture similar to their descriptive statistics. Between 1920 and 1940 their 29-year precipitation patterns are similar, but undergo different trajectories from the 1950s onward. Red Cloud shows a precipitation increase while St. Francis does not.



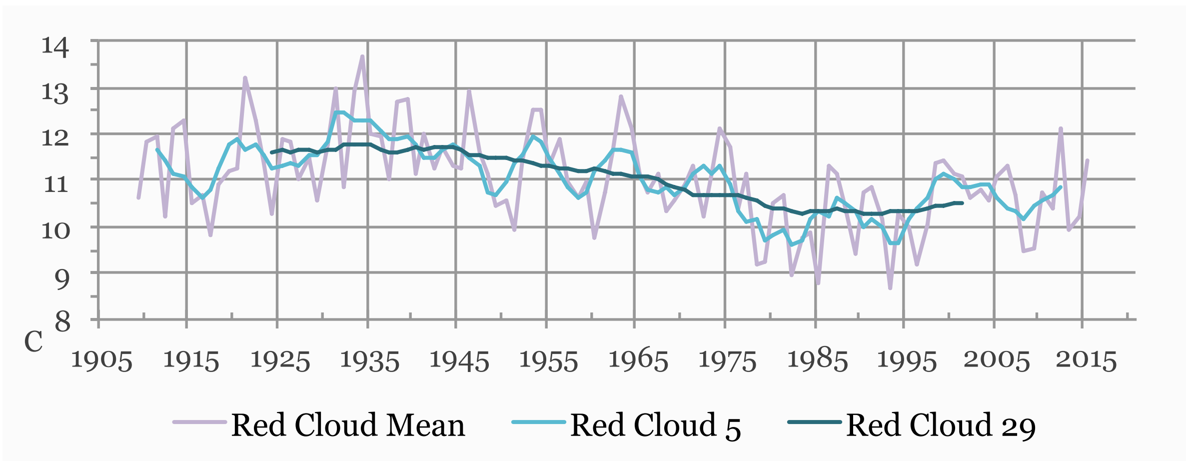


Figure 6.3. Annual Temperature Means for St. Francis, KS (top) and Red Cloud, NE (bottom), 1909-2015. (Author)

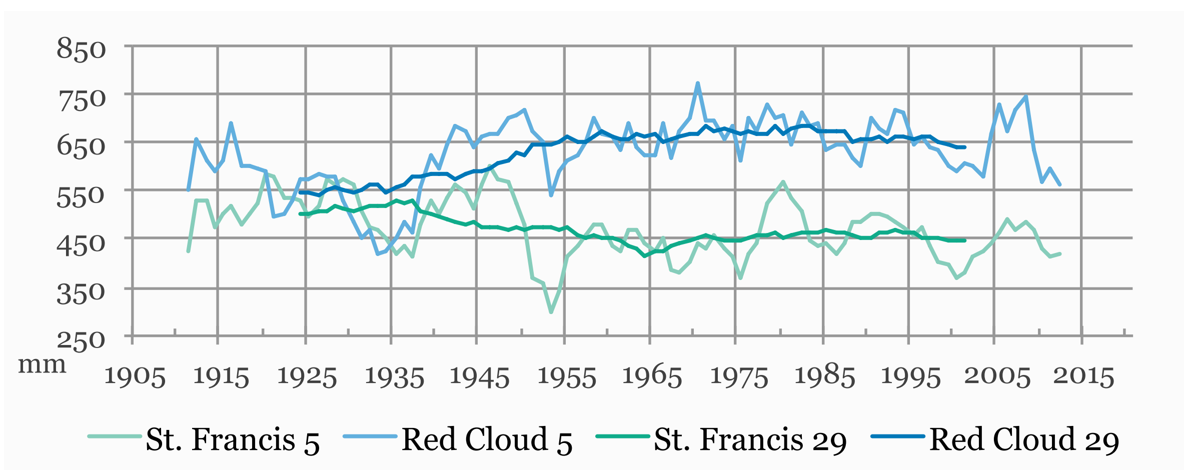


Figure 6.4. Annual Precipitation Means for St. Francis, KS and Red Cloud, NE, 1909-2015 (Author).

STREAMFLOW

Streamflow annual running means present averages over time in acre-feet/year (AFY); these units are common to Compact language and documents. One acre-foot is equivalent to an acre of water one foot deep, about the length of two football fields. Scenario graphics will generally display 5-year annual running means with some 29-year running means included. Additional scenario graphics and log versions for sources and locations are in Appendix B. My discussion will use "streamflow" as a single point in time for situational and event examples, knowing that the actual streamflow value at that point in time may be greater or smaller than the average. Additionally, the FSS accounting procedure has built-in 2- and 5-year averages for states to meet their Compact obligations depending on annual water conditions. Using 5-year running means with my data allows for some alignment with the RRCA. The WB and USGS results are for surface flow, the RRCA for base flow. As a point of reference, the original Compact calculations for annual virgin water in the South Fork are 57,200 AFY; for the entire basin, it is 478,900 AFY (Compact Article III).

COOP WATER BALANCE BUCKET MODEL RESULTS

Twenty-nine-year running means for the hybrid, wet (east), and dry (west) scenarios are found in Figure 6.5. Essentially all the scenarios display precipitation differences as streamflow volume, but their patterns can still be useful. They display data for a 106-year period.

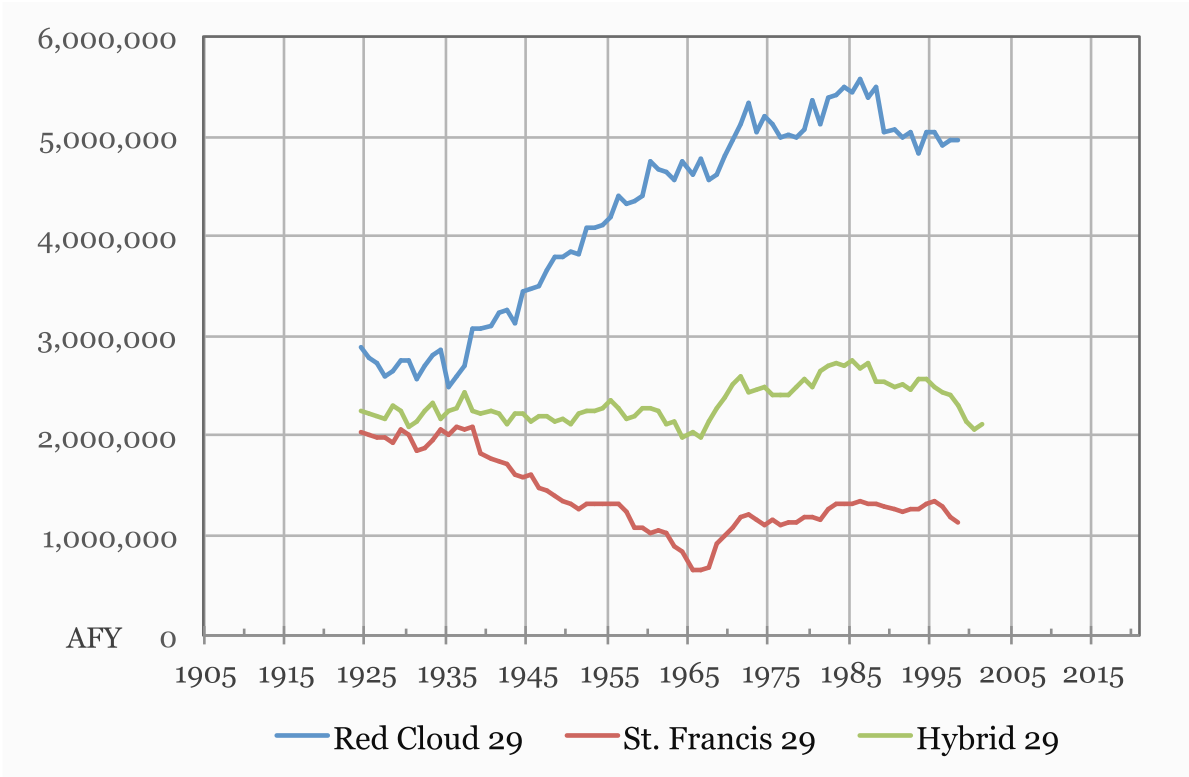


Figure 6.5. Simulated Water Balance Streamflow Scenario 29-Year Means, 1910-2015. Hybrid, Wet (east), and Dry (west) based on Red Cloud, NE and St. Francis, KS COOP data (Author).

The *hybrid* streamflow pattern illustrates a fairly consistent 29-year running mean with flows generally between 2 million and 2.75 million AFY. There is an upward bump from the late 1960's until the mid-1990s. The wet and dry scenarios diverge beginning in the 1940s. The *dry* scenario has a noticeable downward trend, but flows appear fairly consistent at around 1 million AFY beginning in the 1970s for the long-term 29-year trend. An upward trend begins almost immediately for the *wet* scenario and gains some consistency about 1970 onward with streamflows hovering around 5 million AFY. Its gains were about 2 million AFY for a 30-year period (1970-2000). These scenarios are simulated streamflow outcomes based on local weather data from two basin locations; slope, local events, soil type, irrigation, groundwater extraction, and other factors impact actual streamflow.

RRCA GROUNDWATER MODEL RESULTS

Figure 6.6 illustrates annual base flow 5-year running mean results from the acquired RRCA groundwater model data for both the western Benkelman site (on the South Fork) and the eastern Hardy site (on the main stem). The On/Off (irrigation/no irrigation) option simulates what impact groundwater irrigation pumping has on base flows and potentially on surface flows.

The western Benkelman site, with a 5-year mean for both conditions prior to the construction of Bonny Dam and Reservoir, shows virtually identical base flow; these are lines near the bottom of the graph (Figure 6.6, left dashed line). After Bonny's 1951 completion, there's a quick parallel drop in base flow by 50% (~40,000 AFY to < 20,000 AFY). Beginning shortly after 1955, separation between the two conditions is apparent and achieves some consistency in AFY after the 1970s. On/Off conditions mimic each other's upward or downward movement. The upward tick around 2010 represents draining Bonny Reservoir (Figure 6.6, right dashed line).

The eastern Hardy site pattern is not very different from the Benkelman site (see Figure 6.6). The AFY volume is considerably more at Hardy; peak volume for either On/Off is over 250,000 AFY compared to Benkelman's 50,000 AFY. Separation between On/Off occurs a little later and draining Bonny Reservoir is also present in the record.

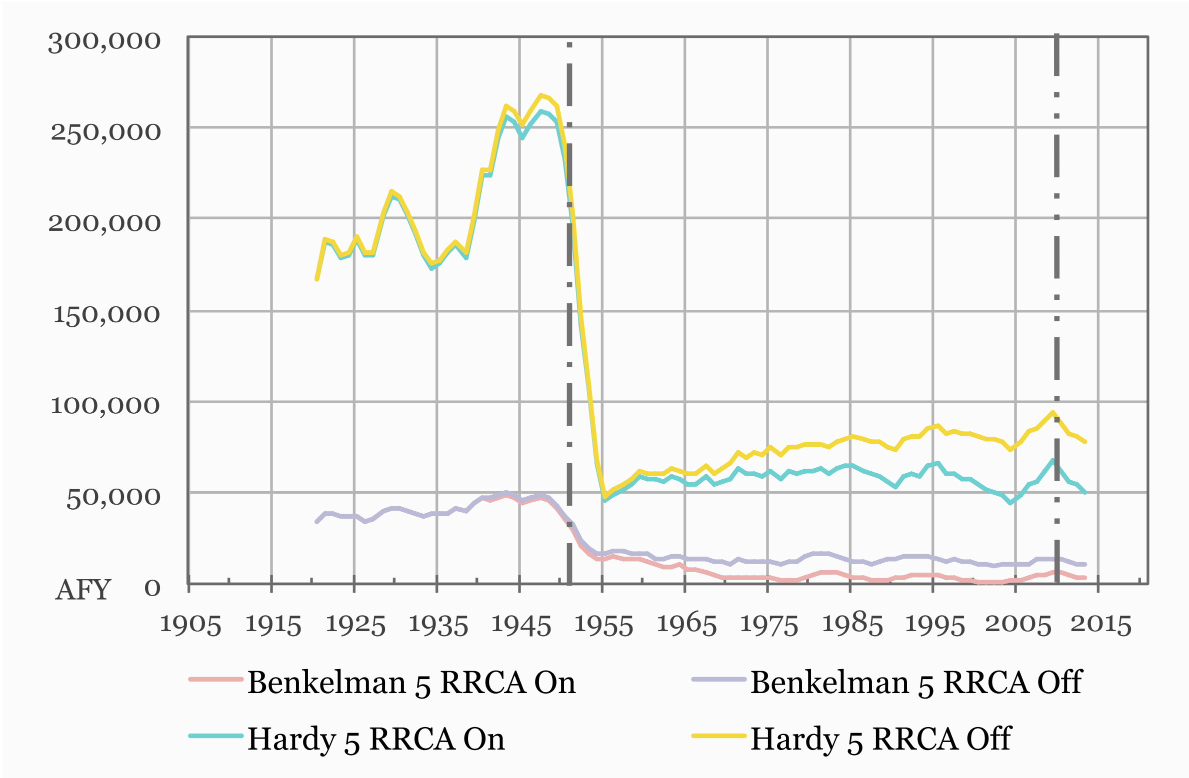


Figure 6.6. RRCA Historical and Pre-Development Annual Base Flow Means, 1918-2015. The South Fork Republican River at Benkelman (bottom) and the Republican River at Hardy (top). Vertical lines represent the completion of Bonny and Harlan Dams (1951 and 1952, left) and draining Bonny (2010-2011, right) (Author).

USGS RESULTS

Figure 6.7 shows USGS Benkelman and Hardy hydrograph annual streamflow results. These graphs are a historical instrumental record compared to the earlier model simulations for the WB and RRCA. Steep declines in streamflow are obvious with the 29-year running mean at Benkelman but not as severe at Hardy.

The Hardy streamflow gauge data has a different trajectory in part due to its shorter record (57 years, versus Benkelman 77 years). The 5-year means illustrate local climate variability, basin size, and basin location; at some periods Hardy has more than 10 times the volume of Benkelman.

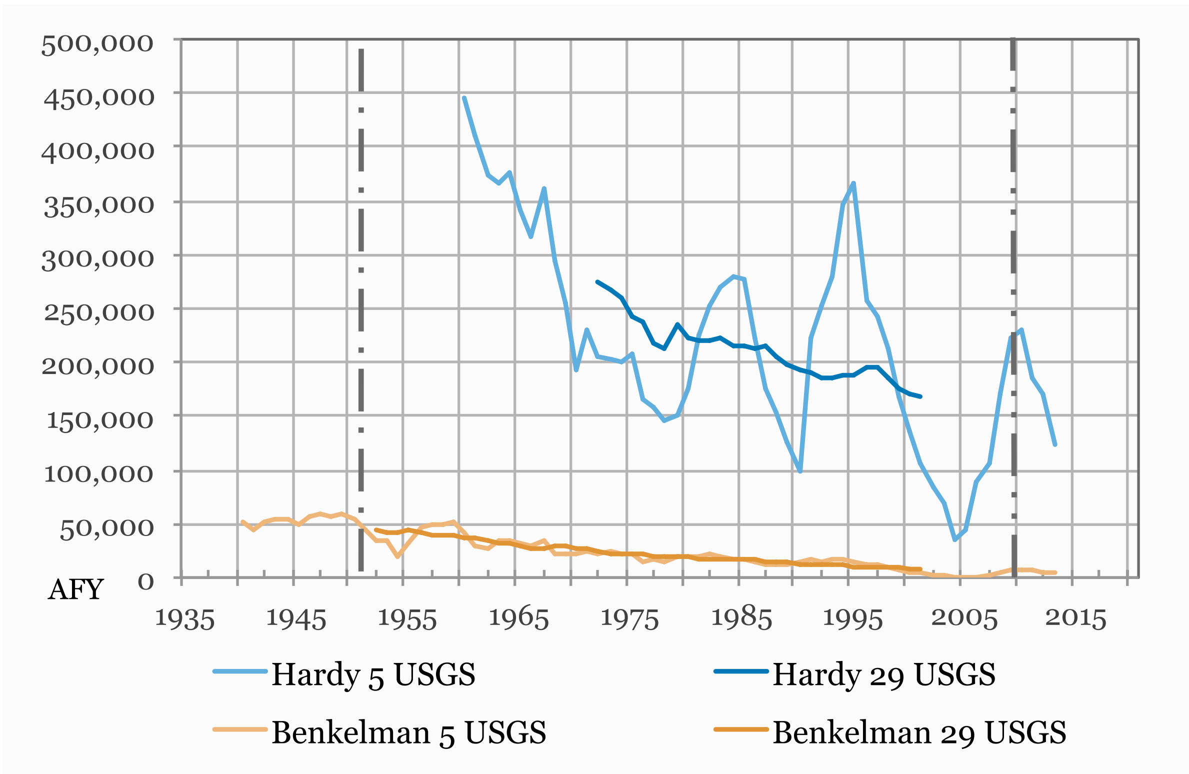


Figure 6.7. USGS Annual Streamflow Means, 1938-2015. The South Fork Republican River at Benkelman (top) and the Republican River at Hardy (bottom). Vertical lines represent the completion of Bonny and Harlan Dams (1951 and 1952, left) and draining Bonny (2010-2011, right) (Author).

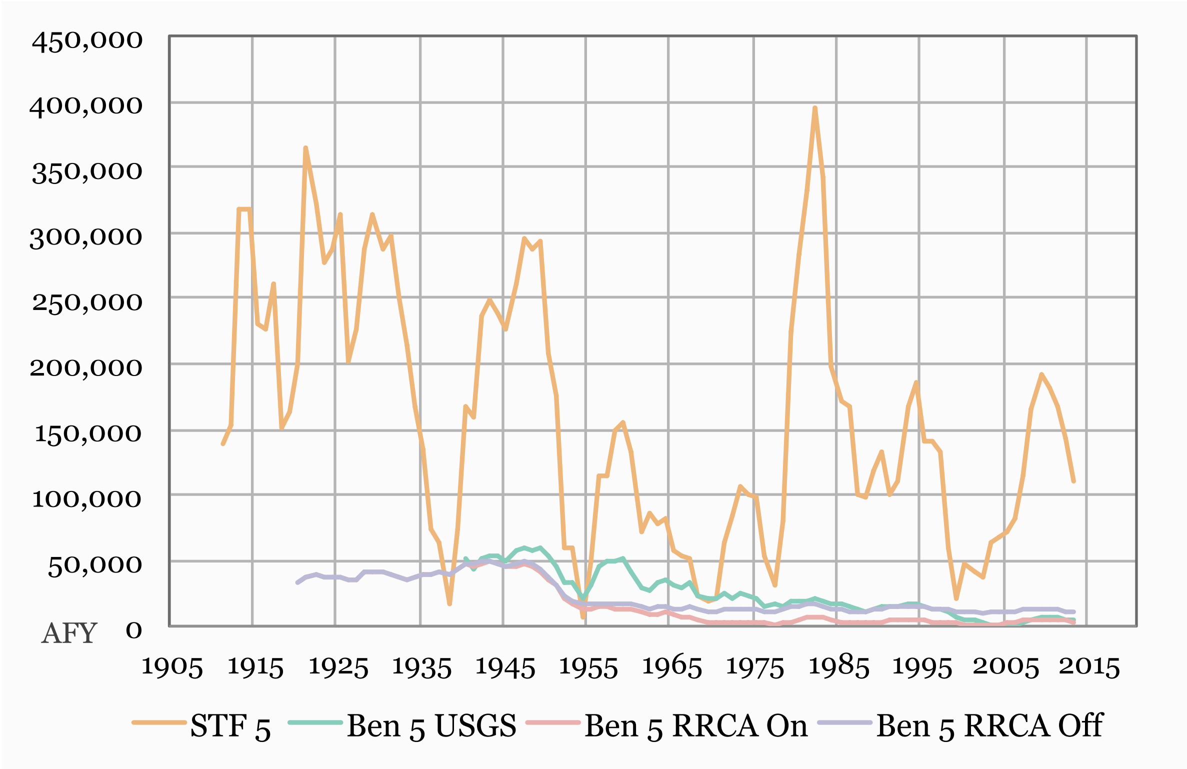
Comparison Results

Figure 6.8 compares all three sources for each of the two basin locations, west and east. The 5-year running mean is displayed in AFY. Other pairings such as COOP WB Red Cloud versus the USGS for Hardy are in Appendix B.

The largest issue for these comparisons is the vastly smaller volume that the USGS instrumental record and RRCA groundwater model show compared to the large volume WB streamflow simulations. I consider the RRCA model a hybrid of sorts since it incorporates instrumental data along with simulating various conditions; it also differs by showing base flow and not streamflow. Those strictures partly explain the differences between the sources and their scenarios. Other factors include simulation assumptions like even temperature distribution or soil type, length of record, local variability, gauge locations, and the role of people. To meaningfully compare these three sources and their results is challenging but possible because the patterns and trends tell a story about the physical dynamics of the basin under differing conditions, a component of the basin's socio-hydrology.

Overall, Figure 6.8 reiterates what the individual graphics have already illustrated between the locations: AFY is climatically and spatially driven, upstream versus downstream or west versus east. Here it is differences between the sources that are foregrounded. A few select highlights between the sources provide some context for their similarities and differences.

Between the COOP WB and the USGS with the 5-year mean in 1983 at Red Cloud/Hardy, there's a 96% difference in AFY (6,268,794 AFY v. 270,430 AFY). Even though the pattern around that time is a bit different at St. Francis/Benkelman, the difference in AFY is 95% (919,778 AFY v. 394,272 AFY). It suggests that despite differences in actual volume, those differences are consistent between the sources regardless of location. They are not realistic. Nonetheless they portray an alternative perspective of the basin's potential streamflow.



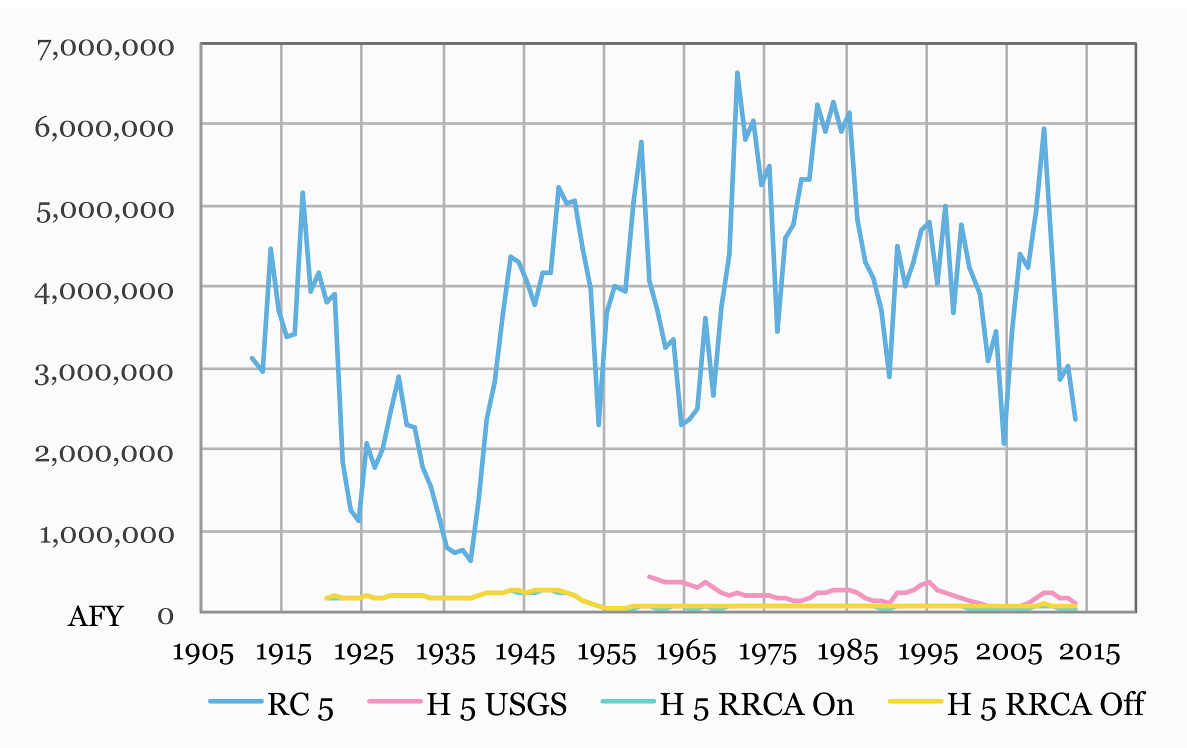


Figure 6.8. Simulated and Actual Streamflow Scenario Means, 1910-2015. St. Francis/Benkelman (top) and Red Cloud/Hardy Sites (bottom) (Author).

The RRCA patterns and results display negative trajectories for base flow, and differ from the USGS's instrumental record for surface flows. (The RRCA calculations include other variables that impact its pattern and trend that are not relevant to the discussion here.) The same can be said for the relationship between the RRCA and the COOP WB results. At times the WB streamflow outpaces the RRCA base flow by 90% at St. Francis/Benkelman, and shows a nearly 70-fold increase in AFY in 1971 (4,800,000 v. 70,000).

Visually examining these three different data sources and the two locations, along with their running means over nearly 100 years highlights and reinforces one point quite readily — the simulated natural (unmanaged) surface streamflow results are considerably different from those of the USGS and the RRCA. The implications of these differences relative to Compact compliance, the guiding questions, and the basin's socio-hydrology are discussed next.

DISCUSSION

Human activity has profoundly shaped the basin's ecological and hydrological systems to the extent that very little if any area remains unchanged. While many of the basin's physical characteristics remain intact like slope, soil type, and topography, human and social structures such as dams, reservoirs, diversion canals, wells, irrigation systems, state borders, and jurisdictional control have redirected and shifted the basin's hydrological cycle to the extent that surface water no longer flows freely and unimpeded downstream. Re-examining the benefits of dams and reservoirs came to the fore with William Graf's seminal "Dam Nation" (1999) article that documents impacts on rivers across the U.S.. He argues that their impact on annual discharge is greater than climate change impacts, and the Great Plains region is one area where the greatest river flow impacts occur. He offers context for policy and science, restoration and economics (Graf 1993, 2001, 2005). For Great Plains' rivers including the Republican, Costigan and Daniels (2012) have documented the need to maintain current hydrological connectivity and encourage natural streamflow regimes especially for rivers that have reservoirs. On the Republican River, their calculations show a negative 65% decline in total annual stream discharge pre- and post-impact at Harlan County Lake Dam. Much of my time series data revealed a similar trend relative to dams and other management decisions on the Republican River.

In the remainder of the discussion, I turn to the guiding questions, how are management decisions presented in the instrumental record? In particular, what management decisions are evident (and which are not) from observational records, and two, can simple models provide additional mechanistic insight into the observed streamflow dynamics?

Management Decisions in the Instrumental Record

Based on the presented scenarios with the USGS data and the RRCA data, three management decisions are easily identified. The first is the impact on streamflow with the completion of dams and reservoirs in the basin. On the South Fork tributary and the Republican River main stem, the completion of Bonny Dam in 1951 and Harlan County Dam in 1952 are distinct. Streamflows decline precipitously after these events. The second is draining Bonny Reservoir in 2010-2011. Each of the management decisions is present in the USGS instrumental record and the RRCA data. A third management decision is more difficult to ascertain, but present none-the-less: groundwater pumping. Cumulative groundwater impacts have directly impacted surface flows of the river and its tributaries (FSS 2002; *Kansas v. Nebraska* 2010; Traylor and Zlotnik 2016). These are evident in the RRCA groundwater model scenarios that depict river system base flows with and without irrigation; irrigation that is largely groundwater generated. Variability between them is obvious and so are the declining base flows; the USGS data shows the same pattern and trends. Although the visual, graphic impact is not as dramatic as the singular dam and reservoir events, its impact through time and space is just as significant to surface water irrigators: less streamflow surface water to use.

What's more difficult to discern with these results i.e., annual running means, are smaller scale choices that irrigation district managers and growers make on a more daily, monthly, or seasonal basis. Some of these decisions may be present in instrumental records depending on data collection practices. Lag times are similarly important as to their direct impact on surface flows. Further, localized extreme weather events can skew the record, masking some water management decisions. Additionally, irrigation district operations and maintenance decisions don't appear either, such as burying irrigation pipe or lining canals and laterals to preserve water and reduce transit losses due to evapotranspiration and seepage; these choices impact streamflow as well. Augmentation plans (pumping groundwater for surface water commitments) are another management decision that is not obviously visible because they can occur over longer periods of time at lower volume, rather than singular large events. A more in-depth spatial and temporal analysis might reveal these choices and events and their impact on the river, its irrigators, and Compact compliance.

The impact of other dam and reservoir completions on upstream tributaries and the main stem don't appear in the instrumental record (USGS or RRCA) at the Hardy site. Not visible at my research scale are the completion of Trenton, Enders, Medicine Creek, and Red Willow Creek Dams. They do not appear at the Hardy gauge because the water is used by upstream FCID, and Harlan County Lake would absorb those events. It is more likely that they would appear in other upstream sub-basin records and gauging sites. Nonetheless, it is unusual that their presence is not recorded farther downstream in the instrumental record.

When policy or management decisions aren't present in an instrumental record, it does not necessarily mean that there is no impact. Rather, those impacts may be smaller than possibly expected, require greater time to appear, or need other tools and techniques to detect changes to the system. In a contemporary world of near instant gratification, waiting for results can be a journey of heroic proportions if it means decades. One irrigation manager commented that had Nebraska begun programs like the IMPs in the 1970s and1980s their irrigation district and farming outlook would be better. "We're down to our last straw for us. We're doing the best we can with what water we do get now, and 10 years from now we don't even know if that's going to be there" (Manager 18). Their observation points out just how difficult it can be to not only implement policy, but also design it and give it time to take root. The Compact statute identifies the ends — equitable allocation and compliance, but the states determine the means. How successful they are relies on their foresight and choices.

SIMPLE MODELS AND MECHANISTIC INSIGHTS

A water balance bucket model and a groundwater model provided data for streamflow scenarios. The scenarios they depict are distinctly different due to their design and purpose, yet provide insights to the rivers' viability and streamflow dynamics. Table 6.4 shows how the water balance and the RRCA groundwater model, along with the USGS data, diverge relative to streamflow on the South Fork of the Republican River. According to the table's data, there was only one 5-year period when the water budget streamflow "matched" observational USGS data, 1970 (1968-1972). The only other similarity between those two is that they both indicate declining streamflows at different volumetric rates. At no time were the WB simulated AFY streamflows similar to any of the RRCA base flow calculations. The disparities between them are large. Even contrasting the RRCA On/Off scenarios illustrate what some may consider stark differences as time moves forward. After 1960 (1958-1962) those differences are significant purely from a base flow perspective let alone for surface flows. Using the RRCA Off scenario and comparing it to the USGS observational record gives two similar periods (1980 and 1990), but it is unlikely that those periods are realistic given the fact that the On scenario is standard operating procedure in the basin, barring a Water Short or Water Call Year by the Nebraska DNR on basin surface water irrigators. Even then, groundwater irrigators outnumber surface water irrigators by a factor of 9:1.

These examples question the ability of the states to meet Compact water minimum allocations. At its ratification, the Compact calculated annual AFY on the South Fork at 57,200 (Article III) and the USGS instrumental record in Table 6.4 ranges from 54,442 to 7,788. Original Compact calculations total 478,900 AFY basin wide for virgin water, surface, and groundwater. The water balance scenarios offer a tease, suggesting that there could be between 47% and 120% more surface water available. Undoubtedly that would be a boon to surface water irrigators and the states if true.

The insights that these models present for the basin's socio-hydrology and streamflows is that people, through water management decisions (particularly infrastructure), have profoundly impacted and changed the river as a natural system and as an ESS and SES component. Despite draw backs and the assumptions necessary to implement these models, they tell us that the river has changed and is likely to continue its current declining trajectory into the foreseeable future without drastic changes to irrigation practices and state water policies.

Table 6.4. South Fork Republican River* Decade Centered Running Mean, Acre Feet/Year

*5-Year Centered Mean***	*Simulated Streamflow (WB)*	*Instrumental Streamflow (USGS)*	*RRCA Modeled Base flow*		*Precipitation (cm/inches) St. Francis COOP*
1950	207,794	54,442	35,498	37,260	34.89 / 13.736
1960	132,628	41,396	12,513	16,308	41.03 / 16.153
1970	21,436	21,414	3,076	11,415	30.38 / 11.960
1980	282,956	18,417	4,977	15,949	58.10 / 22.874
1990	99,571	14,653	3,071	13,548	55.90 / 22.007
2000	47,189	5,697	1,141	10,863	36.89 / 14.523
2010	180,883	7,788	5,859	12,123	44.58 / 17.551

*1943 Republican River Compact Computed Average of Annual Virgin Water Supply for the South Fork of the Republican River: 57,200 AFY

**listed years are centered dates (1950=1948-1952)

(Author)

CONCLUSION

Three conclusions can be drawn from the streamflow analyses using instrumental records and (simple) models. One, water management decisions are present in the instrumental record, especially for large scale infrastructure projects and Compact water compliance obligations. Two, river surface and base flows are declining spatially and temporally as documented with USGS instrumental and RRCA model results. Three, simple models like a water balance model serve as a counterweight to instrumental records by presenting simulations that challenge the value of streamflow management.

Regional climatic outlooks are not particularly favorable for water users, crop impacts, and aquifer recharge with increasing temperatures, higher evaporation rates, and shifting precipitation delivery timing that can impact irrigation user decisions (Brown and Rosenburg 1999; Rosenberg et al. 1999; IPCC 2007, 2013, 2014; Mearns et al. 2012; Mearns et al. 2013). Irrigation itself can have an impact on regional climate (Huber et al. 2014). Water demands and stresses are likely to accelerate and pressure local water boards, state legislatures, and the judiciary to provide political fixes that protect uses and users; solutions that could be politically contentious.

In the Republican River basin, irrigation district surface water users who depend solely on streamflow are becoming a threatened and endangered species whether they farm in Nebraska or Kansas. Colorado surface water irrigators are already on the endangered list with fewer and fewer using it (Deb Daniels, Manager RRWCD, pers. comm. 2016). Declining streamflows and surface water jeopardizes their livelihoods and those of their rural agricultural communities, their region, and their state. Alternative methods and technologies will be needed to address these declines, provide water to surface water users, and keep upstream Colorado and Nebraska Compact-compliant with Kansas. Farmers are resilient and innovative, but without the supplemental irrigation water from the river, their economic productivity may go the way of the river, dry.

CHAPTER 7
COMPACT AND WATER PERCEPTIONS

Interviews can be a powerful voice for participants and researchers alike. With well thought out questions and a skillful interviewer, they can offer personal insights, experiences, and context that are difficult to convey with quantitative data (Drever 1995; Dunn 2010). Statistical data from the USDA Agricultural Census, the U.S. Census, or the National Weather Service tell a story at a specific scale, for a specific place, and for specific phenomena that may obscure underlying motivations and decision-making by individuals or groups. Interviews can foreground those reasons and led to a richer understanding of a situation, contrast interpretations, as well as engage both parties in unexpected manners (Dunn 2010; Delyser and Sui 2013; Dowling et al. 2016). Take this interview comment from a Republican River basin stakeholder about water augmentation plans by Nebraska to meet its Compact requirements:

> The key to water law is to protect existing users .... There was no permit given to N-CORPE .... They have pumped a heck of a lot of water, [but] say in public that we're not going to pump any more than was consumptively used before they retired those wells .... Well, they clearly have in the last few years .... There's no assurance that in fact they aren't over pumping. That's my problem. Manager 1.

It clearly illustrates how some stakeholders question the legitimacy of the Nebraska augmentation plans and a desire for transparency. It is necessary to understand state and NRD management decisions. Context for discord between basin actors about the augmentation process, and its potential long-term use and impact, is provided by the comment. Simply compiling a list of lawsuits or acre-feet/year pumped would not be an accurate picture as to why augmentation is being used and why it is being challenged.

Few scholarly resources regarding actor engagement and opinions in the Republican River basin exist (Woudenberg 2007; Sambol 2010; NRD Oral History Project n.d.) with a far greater number focused on hydrological or economic impacts (Johnson 1960; Perkins and Sophocleous 1999; Szilagyi 1999, 2001; Sophocleous 2000; Sophocleous and Perkins 2000; Szilagyi et al. 2003, 2005; Wen and Chen 2005; Choodegowda 2009; Brosovic and Islam 2010; Crosbie et al. 2013; Juchems et al. 2013; Brookfield and Wilson 2015). I determined that more focused research was needed on human actors in the basin and interviews were a viable tool to achieve that goal. Interview results can be allied with other components like policy and streamflow assessment as part of the basin's profile to lend greater depth and understanding to water management decision-making in the Republican River basin and under Compact provisions and requirements.

The remainder of the chapter is divided into interview methods, results, and conclusion. Methods and results are further subdivided into more specific sub-topics. The methods section begins with a general overview and rationale for semi-structured interviews, my pre-interview methods, the interviews, and post-interview methods. Results include question responses, themes, and limitations and recommendations.

RESEARCH INTERVIEW METHODS

Interviews may occur as structured, semi-structured, or unstructured and be placed on a continuum for organization and format. Structured interviews tend to be highly formulated, with predetermined questions and presentation order, as opposed to unstructured interviews that take a more free-form approach with each interviewee. Semi-structured interviews are fluid conversations like unstructured interviews, while at the same time designed to elicit responses to key questions or words that were selected based on background information or associated research literature (Drever 1995; Dunn 2010). Structured interviews take a positivist approach while the others may fit better within more post-positivist epistemologies (Denzin and Lincoln 1998). Furthermore, Denzin and Lincoln (1998) emphasize that qualitative research tackles socially constructed realities, situational constraints, and relationships between researcher and the researched; components of my research and interview methodology.

A well thought out purpose and series of questions can assist in answering a research question particularly for structured and semi-structured situations (Drever 1995; Dunn 2010). Questions may be described as primary, centered on a specific topic, or secondary, such as clarification questions. In any case, simple unambiguous wording that is respectful and non-leading is best used during interviews (Dunn 2010). Use of semi-structured interviews have a long history of use in qualitative (human) geography research and enhances how we understand how people relate to and shape place (Dowling et al. 2016). Dowling et al. (2016) contend that interviews enhance qualitative human geography because they can enfold "the socio-materiality of human life and interrogation of the concept of representation in constructing knowledge" (684).

Semi-structured interviews have been used to understand water transfers in southern Nevada (Welsh and Endter-Wada 2017a), water resource management and governance in the U.S., Canada and elsewhere (Noble et al. 2014; Franzen et al. 2015; Mees et al. 2017), ecosystem services in Australia and Spain (Macdonald, Bark, and Coggan 2014; Felipe-Lucia et al. 2015), Spanish irrigation sustainability (Ricart et al. 2016) and climate and water in North and South American case studies (Farley et al. 2011; Hurlbert and Gupta 2016).

I chose semi-structured interviews as the best method to solicit information and perspectives about the basin from irrigation district managers, growers, and other relevant actors. They can provide insights about their motivations and concerns regarding water management decision-making at multiple hierarchical levels. The format allowed me to focus on key topics like water management and the Compact, while at the same time allow for flexibility to follow topics that concerned interviewees.

Pre-Interview Methods

Based on my basin research readings from peer-reviewed journals, public documents, and other sources, I made a list of potential questions for the stakeholders about the basin, the Compact, and water. I pre-tested the questions with a knowledgeable individual who had previously worked within the Republican River basin. Questions were re-worked and re-focused from their input in response to pre-testing. The initial questions were winnowed to six that focused on key topics that I felt would best shed light on the actors' relationships with water, the Compact, and between each other. Questions were designed with a semi-structured format, interviews were anticipated to take about an hour, and results would be both anonymous and confidential to safeguard individuals' participation, along with fostering trust. All research interviews adhere to the University of Kansas Office of Research guidelines, which included training, material submission, and evaluation. Approved questions are listed in Table 7.1.

Once I received approval, I identified the specific people and groups in the basin who I felt could directly address the questions based on their profession and personal experiences with water and the Compact. Primarily these individuals were water managers at local, state, and federal entities, along with agricultural growers. They were contacted either via email or phone to solicit their participation or take recommendations for someone who they felt might be equally or more helpful to my research, a common referral methodology known as a snowball technique. Once participation was confirmed, we set up a date, time and place to meet, so that I could conduct their interview. None of the contacted participants declined interviews.

Table 7.1. Interview Questions

1. Could you tell me about the short- and long-term water management challenges you have in your district for your users, and the impact those may have on receiving water plus meeting the Republican River Compact requirements?

2. Augmentation plans in Colorado and Nebraska have been implemented to ensure that water is available and deliverable to downstream users. How do you perceive their short- and long-term augmentation viability for your district and the Compact?

3. What steps has your district considered in response to predicted temperature increases and precipitation decreases, e.g., higher temperature minimums and less water during the growing season for the region and basin? What kind of response have they received?

4. What kind of collaboration has your district participated in to manage water in the basin? Has it been beneficial to your district and its ability to meet Republican River Compact requirements?

5. Have conjunctive use and correlative rights changed water management in the basin generally and in your district specifically? If so, in what way?

6. What else would you like me to know about your district, the basin or the Compact regarding water or its management?

POSITION STATEMENT

As an academic, a resident of south central Nebraska and a temporary resident of Kansas, and a woman, my positionality plays a role in my research about the Republican River basin and Compact. Any research process seeks to answer questions; in turn confirming or refuting assumed answers and checking biases. I discuss my positions next relative to the interview process.

First, I am both an insider and an outsider to the Republican River basin. I am an insider because I live in Nebraska within a short distance of the river basin, and therefore I am aware of regional events in a general sense. I am an outsider because I am not a farmer nor directly connected to the agricultural economy of the basin, including how the irrigators and the irrigation districts manage water. Second, I am an academic approaching highly personal issues in the form of water shortages, legal disputes, and intra-agency relationships for the residents and irrigators of the basin from a critical, objective position. Maintaining objectivity when faced by people with real and legitimate concerns about their livelihoods is a tight rope act. In particular, building rapport and trust with key basin stakeholders in order to solicit honest answers about their relationships and perspectives about water, legal issues, and agricultural practices requires flexibility and honesty on my side, too. Third, as a woman and academic researcher, I explored an area largely dominated by men. How my gender may or may not influence my research could have a bearing on data collection and interpersonal relationships with the interviewees and other people. Except for two interviews, all my participants were men. In each instance, I felt that they accepted me as a knowledgeable person and were respectful and helpful as I pursued my research, either in person, on the phone, or by email. As an in-person interviewer, I learned to listen more and talk less. By the end of my dissertation research and writing, I gained new insights into the basin's management and social complexity, garnered a deeper appreciation of the decision challenges facing irrigators, and discovered that legal decisions have a far greater impact on water management decision-making than water itself when those decisions result in less water availability.

Interviews

Interviews took place between January and June 2016, and occurred at the participants' convenience for time and location. All interviews were in-person except for one phone interview. I began the interviews by introducing myself, telling them about the project, and giving them a chance to ask their own questions in order to help them feel comfortable and build a level of trust and rapport (Drever 1995; Dunn 2010). Interviews were recorded with a digital recorder with the participant's consent along with their verbal acceptance of the interview conditions of confidentiality and anonymity (Appendix C). Questions were not necessarily asked in numerical order depending on the conversation. Responses to the questions were scattered throughout, as were follow-up and corollary questions and answers. Periodically during the interview, I would check the question list to verify that answers had been given in response to either direct questions from me, had already been answered as part of the conversation, or had not yet been addressed. In the last case, I would insert it during an appropriate moment. Conversations tended to take on a rather free flowing and informal air. In this way, I was able to gather information that addressed my research agenda, but was also able to acquire commentary on issues and experiences that were important to them and their relationship to the basin and other actors.

I provided each participant my business card for contact information if they later had other questions or comments to share. At the conclusion of our conversation, I thanked them for their time and participation, offering to share my results and conclusions with them either in person, at a public meeting, or through published reports and articles. I have continued to be in contact with many of the participants via email or phone calls as well as various relevant Republican River meetings. My interest in the basin remains unabated, and I believe that continued interaction demonstrates my commitment to the challenges facing the basin residents.

Post-Interview Methods

To ensure confidentiality, interview recordings were saved to a secure and encrypted computer software file. I listened to the interviews and took notes, identifying common themes, points of conflict or consensus, responses to the semi-structured interview questions, and select quotations that could be useful in the analysis and to the dissertation. Because interviews were anonymous and confidential, full transcripts are not included in my dissertation. Select quotes are used to support arguments and provide motivational insights and are anonymously attributed as a grower or manager.

Interviews were assigned to one of four categories based on the stakeholders' identification to create a cohort of like basin actors who have perspectives and experiences that reflect the basin's water management history and current water situation.

- *Contextual interviews* provided historical background from the Compact's beginnings, past activity, and legal issues, for example. Interviews with retired or former employees typically fell here.
- *Special initiatives* were non-state and non-federal groups or organizations and their members who were engaged in some type of basin activity including field and technical experiments. NEWBA, the Nebraska Water Balance Alliance, who promotes a basin-wide approach to water management throughout Nebraska, allowed me to attend a few grower meetings and was assigned here.
- *Regional managers and director's* interviews focused on those individuals who may occupy management positions at the state or federal level. State level bureaucrats were classed, here, for example.
- *Irrigation district interviews* were exclusive to irrigation growers and irrigation district managers, since they are at the front line of water use and management decision impacts.

A few individuals fell into more than one category, such as contextual and special initiatives, but I placed them by their primary role. A second step was coding interviews for themes. I listened to each interview, identified key topics from it including augmentation plans, pivots, and taxes, and collated all the interviews to assemble a list of unifying themes that re-occurred throughout the process.

Interview Results

In total, twenty-one interviews were completed with current and former basin stakeholders that included local area growers and irrigation district managers, and local, state, and federal agencies. Interviews were either done with individuals or with groups, as was the case with the irrigation district boards. The actual number of individual participants is greater than the number of interviews. They were placed into one of the four interview categories: contextual (three interviews), special initiatives (three interviews), regional managers and directors (eight interviews), and irrigation districts (seven interviews with 13 people).

My analysis focuses on the irrigation district interviews because these stakeholders are the most directly impacted by water fluctuations, hierarchical management decisions, and meeting Compact compliance at the river. The irrigation district interviews included current and former managers and district board members, all local growers and land owners. The other interviews are equally valuable and provide additional context for current and past basin activity, but were not analyzed in-depth at this time. Irrigation districts and their members are the dissertation's emphasis.

Interview Question Responses

Short- and long-term water management challenges (question 1) were answered at length by all the participants, often in conjunction with augmentation plan viability (question 2) and relative to the Compact itself. Generally, respondents indicated a desire for longer-term stability, equitable treatment, and clear channels of authority. Climate change (question 3) had very limited voluntary responses, with stakeholders downplaying its immediate role in the basin. Collaborative measures (question 4) were discussed in all the interviews, but with varying intensity depending on the stakeholders and their participation in such activities. All the districts apply for and have received grants from various entities, often state or federal programs that could fall under collaborative measures. The Bureau of Reclamation's 2012 Water SMART grant program was one such activity. All three states contributed to understanding current and future water use demands and decisions, and explored alternative strategies for the Republican River basin (Shellpeper 2012). Another was the *Republican River Basin Study* completed with the Bureau of Reclamation. Conjunctive and correlative rights (question 5) were only mentioned once in the interviews, and in a follow-up phone call, the participants agreed that they had little direct impact on the irrigation districts at this time. Based on the conversations, the topic did not warrant special attention. Additional information about their district and specific situation (question 6) varied by group, and depended on what had been discussed previously along with the duration of the interview itself. Most reiterated the need for equity, sustainability, and having a voice in the larger basin ecosystem, especially governance decisions beyond their irrigation districts.

For most of the interviews, unless one of the questions was asked and answered specifically, it was difficult to definitively capture direct answers in reviewing the tape, particularly because the questions and topics overlapped so closely and were focused on broad management issues relative to meeting Compact requirements in one form or another. Thus, any answer could address short- and long-term challenges, augmentation plans, collaborative planning, or any other combination. Further, follow-up or clarifying questions to stakeholder comments provide information about a topic important to them. No discernable difference was apparent between the Kansas and Nebraska interview responses, other than the acknowledgement that some locations were either upstream or downstream of other users and that each state has their own water policy and practices. Current events at the time of the interviews in Spring 2016 (multiple lawsuits by the Nebraska irrigation districts against the Nebraska DNR), colored their responses to some extent, although I believe that they were open and honest to the degree they felt comfortable. I was not asking them about the lawsuits or to disclose privileged information. In particular, this was the case for one irrigation district when I interviewed them shortly after the district had filed a lawsuit.

Interview Response Themes

Themes are a common way of grouping participant responses to quantify a topic's consistency, show assimilation or divergence between stakeholders or places, or highlight unique situations. I evaluated interview responses based on key words or phrases like augmentation, taxes, pivots, or water, to identify common stakeholder themes and concerns.

Six broad themes emerged throughout the interviews: Governance, Conservation, Water, Economics, Legal, and Miscellaneous. Some themes were more robust in terms of time allocated to their discussion, but these six appeared consistently. Each theme is built on key words and phrases that support the larger scale picture. For example, the comment "For the farmers, if surface is turned off, then tax us as dry, but it will wreck the counties to do it" (Manager 5) would primarily fall under the Economics theme, specific to tax, a key word, but could also be important to a discussion on Water or Governance, depending on the discussion's context. Major themes and key words are found in Table 7.2, and Table 7.3 presents select quotes for each of the six key questions and matches them to major themes; the primary theme is listed first.

TABLE 7.2. Interview Themes with Key Words and Phrases

GOVERNANCE	Republican River Compact, irrigation district board of directors, irrigation districts, state agencies, statues and policies, federal agencies, states
WATER	Surface water, groundwater, irrigation pivots, wells, project water, Warren Act water, water storage, water competition, equitable allocations, storage, augmentation, Rock Creek, N-CORPE, Colorado, trans-basin diversion
CONSERVATION	Irrigation pipe (surface and buried), irrigation pivots, reduced use, technology (soil probes, ET gauges, drones, GPS), sustainability, storage
ECONOMICS	Taxes (occupation and property), costs, inputs, community
LEGAL	Republican River Compact, water law, lawsuits, state statutes
MISCELLANEOUS	Media coverage, basin vision, specially organized groups or meetings

Governance broadly covered how policy at multiple scales was enacted and enforced and who had the authority or power to do so. What was most concerning to stakeholders was the lack of a clear hierarchy outside their irrigation district, especially in Nebraska. Who is in charge? Is it Reclamation, the State, the NRD? Are we going to get our water? Anything water associated counted as the Water theme. Here participants expressed a broad spectrum of opinion that was usually centered on allocations, usage, augmentation, and every other theme. The Conservation theme was closely related to water and economics, but more often focused on reduced use and sustainability from a technological perspective as well as associated costs to achieve greater efficiency.

Economics tended to lean primarily towards taxes at the county and irrigation district level, particularly occupation and property taxes as they relate to irrigated acres and whether they were surface or groundwater, since the taxable values differed. At KBID, they

> have a per acre charges and it has nothing to do with how much water you get, whether we are at a full supply or a zero supply, they're charged. If you're in an irrigation district and you have classed acres, you're classed acres. Classed acres are irrigable acres .... You pay about $44.50 and $43.75 per acre. That's two different charges because one is for Class I and II acres, and the other one is for Class III and IV .... I and II is supposedly premium and III and IV is maybe not as east to irrigate, so it's a little bit cheaper (Pete Giles, KBID Manager, pers. comm. 2016).

In Nebraska, rural and urban taxpayers are assigned to and pay an NRD tax; as an irrigator with FCID or NBID, the grower pays an irrigation district tax, too.

The Legal theme focused explicitly on legal conflicts, most specifically lawsuits at the federal and state level as they related to over-use and "takings," denying irrigators their water so that it could be sent to Kansas and not being economically compensated by the state. The Miscellaneous theme was a catch-all of sorts, collecting topics that the participants addressed during the interview, may not have been present in other interviews, or did not fit easily into one of the other themes. These were still important for understanding people's perceptions about the basin's socio-hydrology.

Table 7.3. Select Question Responses and Their Themes

QUESTION AND RESPONSE	THEME
1. Water management challenges	
• "We have a religious problem. God gave us the rain and the water, but we don't have Jesus but we have a hell of a lot of disciples running around. We need the Jesus to coordinate these people. And that's what we're missing." Manager 4.	• Water, Governance, Conservation
• "We want a full supply-we'd love to have a larger supply. The Compact protects for so much water. The districts wouldn't be here without the Compact …. We as Kansas Bostwick, we should get whatever the Compact allows and it's up to us to take care of it, to make it work for us." Manager 7	• Governance, Water, Conservation
2. Augmentation plan viability	
• "The augmentation plans are dancing around rather than saying [we] have to cut 10%." Manager 4	• Water, Governance, Conservation
• "We suffer depletions because of over pumping [in Nebraska] …. directly related to groundwater depletions. Precipitation amounts haven't changed much. We have to look long-term to see any amount of change …. more groundwater change than weather." Manager 7	• Water, Conservation
• "[It's a] helpful tool [N-CORPE] if not abused, but there's no statute in place to prevent abuse." Grower 9 "Okay as a band aid, …." Manager 3 "but using 10 of 10 [years], still pumping 30,000 acre feet." Grower 8	• Water, Legal
3. Climate change impacts	
• "Tree ring data tells use we're in a wet period with average rainfalls." Manager 4	• Water, Conservation
• "They've made some grant money available [for climate]. We've had three grants the last four years. More efficiency helps, but that's some [garbled] reasoning to be prepared for climate change going forward." Manager 3	• Conservation, Economics

Table 7.3. (continued)

QUESTION AND RESPONSE	THEME
4. Collaborative measures	
• "In 2013, our users wanted a community forum [to talk about who is in charge], so we invited the DNR and the NRDs. The DNR does not want to come because they're afraid of libel. NRD says DNR runs it, DNR says NRDs run it." Manager 4	• Governance, Water, Law
• "I was part of the [Nebraska] Water Sustainability Task Force two years? four years ago? and at the last meeting we had to define sustainability. They wanted consensus and I said no because groundwater augmentation was included. I said if they took it off then I'd say yes, so they took it off, but by October it was back on. The same thing will happen with the Basin Wide plan." Grower 7	• Water, Governance, Conservation
5. Conjunctive and correlative rights	
• Conjunctive use and correlative rights were not directly addressed, and if asked about them, participants indicated they were unimportant at this time.	
6. Additional information	
• "If they [media] try to impartially evaluate, I think the NRDs would sue because they want control of what comes out." Manager 4	• Miscellaneous
• "Water is our lifeblood here. We still have two schools and the next county over they've got one. If it wasn't for the irrigation we wouldn't have a tractor dealership...Courtland would look different. Just our lifeblood. The feedlot, ethanol plant — wouldn't be if wasn't for that." Grower 4	• Water, Economics

RESEARCH INTERVIEW LIMITATIONS AND RECOMMENDATIONS

As with any research endeavor, limitations and shortfalls are inevitable. Due to the nature of semi-structured interviews and my rather freeform approach, some topics and opinions may have been overlooked. However, ample opportunities were present for sharing ideas, especially with the concluding question. Particularly in the group interviews, some participants might have felt either more or less comfortable speaking in a group or were restrained because I was unfamiliar. I would encourage other researchers who want to use an interview methodology to build early relationships with potential interviewees by talking with them on the phone, emailing them for information, and attending meetings and introducing yourself to them. By showing an interest in their livelihoods and profession, people are more willing to participate, especially if it can help them. Everyone was more than happy to speak with me, but in a few cases, it was initially a bit awkward.

The interviews served their intended purpose of gaining stakeholder perspectives about their experiences and expectations in the basin, and how those viewpoints contribute to actor relationships and the basin's socio-hydrology. Further, they helped to identify how the basin stakeholders had socially constructed their space.

CONCLUSION

My overwhelming impression after speaking with the managers, boards, and growers of the three irrigation districts was their strong desire for reliable water over the long-term, a time that was not identified. In Nebraska, many of the interviewees had both surface and groundwater rights, as opposed to KBID where they only have surface water rights. Regardless of the location or type of water right, these growers, and the managers who work for them, want to know that they are going to have enough water to grow a viable crop and meet their financial commitments. If they could, they would want their irrigation water number in late fall or early winter, so that they can make input decisions about seed when the seed companies offer their best discounts. However, climatically that is not possible. They also believe that all the growers in the basin need to abide by rules and regulations equally; there cannot be one standard for surface water and another one for groundwater. Grower 7 said that,

> the argument for guys west 80-100 miles say they need more water because they get less rain. Maybe they shouldn't grow such high water use crops in an arid region. Allowing them to pump more water reduces our streamflows downstream. If we all went to equal amounts for groundwater pumping… eventually land value would adjust and reflect that.

When there is equity there can be reliability and sustainability, at least from the perspective presented here.

Governance was equally important to them, specifically authority and oversight as it related to legal issues. The bureaucratic hierarchy appears straightforward, but it is not. The Nebraska DNR can make a Water Call or designate a Water Short Year that declares limits on the amount of water available to the irrigation districts. That action directly impacts the Frenchman-Cambridge and Nebraska Bostwick districts. Confusion arises when there are competing policies and obligations between the states, Reclamation, and NBID over water accessibility. From 2004-2007 NBID received no outflows from Harlan County Lake, while KBID received none for 2004 and 2005 (Manager 4 and Manager 6). NBID therefore saw water flow past their irrigators to KBID irrigators for two years in order to make sure that the state was compliant with Kansas and the Compact (Manager 4). Kansas's 2010 lawsuit claimed that Nebraska had overused water in 2005 and 2006 by 35,000 AFY each year. NBID was not getting water from Harlan in either of those years and Kansas was getting some water in 2006. Thus, the confusion over who gets water when, and by what regulation.

Adding another layer to the irrigation districts' uncertainty is the fact that they are not directly named in the Compact. Although most of the parties would agree that these three are the beneficiaries of the basin's water, the states technically may be under no obligation to provide it. Reclamation has to follow state laws, but at the same time they have an obligation to provide some level of support and protection to their irrigation projects. These circumstances put the irrigation districts, particularly FCID and NBID in Nebraska, in difficult water and legal limbo, thus their ongoing demand for clear jurisdictional authority.

The people who I interviewed were largely interested in pursuing solutions, independently or in partnership, as long as they believe there is a level of trust and both parties are acting in good faith. They see lawsuits as a last resort when all other avenues have been blocked and/or agencies and actors have been unresponsive to their concerns. Ironically the Compact itself states that one of its purposes is "to remove all causes, present and future, which might lead to controversy" (Article I). One manager colorfully described the basin as a religious problem where "God gave us the rain and the water, but we don't have a Jesus, but we have a hell of a lot of disciples running around" (Manager 4).

The growers are interested in long-term sustainability, especially for surface water. As groundwater pumping affects surface flows and available water for surface irrigators both in the present and the future, they want measures and policy implementation that can support some degree of an annual reliable and usable volume of water. It means groundwater regulation and enforcement, something that Nebraska is loath to do for groundwater because of the contingent's political clout; with 90% groundwater irrigators compared to 10% surface irrigators, their collective political power is considerable (Griggs 2017). Yes, if a grower has groundwater rights, they can adjust which fields are irrigated, eliminate marginal acreage, and concentrate on the most productive fields, but it still limits their production capacity; the same holds true for surface irrigators. For those growers with groundwater irrigation wells in Nebraska's Rapid Response area, they question just how beneficial a well shut down can be in its various zones (Figure 7.1). First, there's a fairly significant lag time between well shut down and surface flow rebound. Second, they want to know if their well is hydrologically connected before they are shut down and stop pumping. Surface water irrigators contend that well shut downs may not be very practical in the short-term. For longer projections, the shut downs remain a possibility. Growers will continue to innovate, adapt, and deploy new technology that allows them to maintain harvest yields with less water especially when their allocations continue to shrink. If no water comes through the diversions and ditches due to a water call, low precipitation, or drought, those steps are not enough.

The basin stakeholders want to be heard. They want the larger public and all state representatives to understand the challenges in the basin and to support them beyond transitory news headlines that pop up when a new lawsuit is filed or a water call is put into place (Knapp 2013, 2015; Baker 2016; Bergin 2016; *McCook Gazette* 2017). They want the urban cores to know that they use water wisely, they support the state economy, and they are an important part of their state's social fabric. State agriculture generally in Kansas is the largest percentage of the state's economy at ~44.5% contributing nearly $67.5 billion (KDA 2017a). For Nebraska, agricultural jobs are 25% of its workforce, and farm marketing cash receipts were over $23 billion in 2015, which is 6.1% of the U.S. total (Nebraska Department of Agriculture

2017). These are smart people who are knowledgeable and well versed in their area of expertise, agriculture, pay attention to state and federal legislation that will impact their businesses, have internet access, use the newest technologies to monitor their fields, and travel internationally. I have the utmost respect for the businesses they run and the conditions under which they operate them.

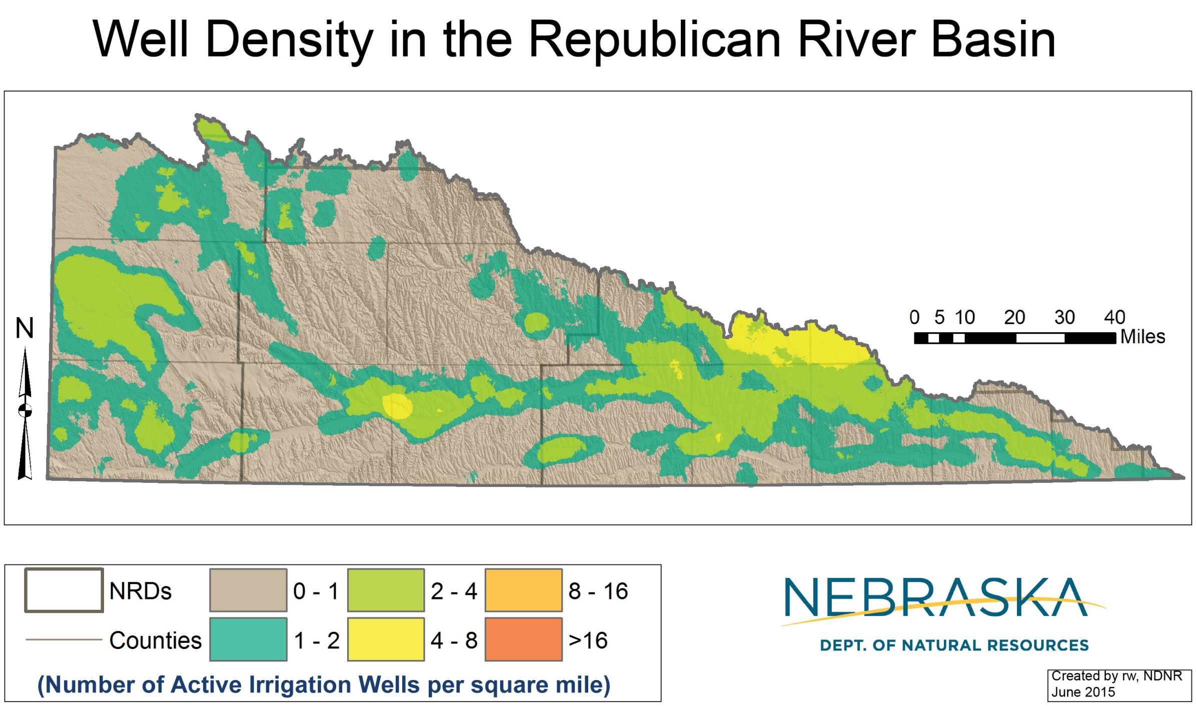


Figure 7.1. Nebraska Republican River Basin Irrigation Well Density. Rapid Response Wells are typically located in the valley as opposed to the upland areas (NDNR n.d.).

Irrigated agriculture is the backbone of the Republican River basin whether it is Colorado, Kansas, or Nebraska. In 2016, harvested irrigated corn in bushels/acre was 211.7 in Nebraska's upper basin Perkins County (a northwestern county) while non-irrigated corn was 83.3 bushels/acre, a difference of 128.4 bushels/acre that is nearly 54% more than the non-irrigated harvest average. In Nebraska's lower basin Franklin County, the difference was 78.4 bushels/acre (206.6 irrigated v. 128.2 non-irrigated) and in Kansas's Republic County harvested corn was 156.5 bushels/acre (irrigated and non-irrigated values were not given) (USDA 2017), almost 30% less than Perkins County. Impact to Republic County from agriculture and related activities has an added value of over $73 million and an output of over $250 million (KDA 2017b). These sample production differences and economic impacts are not insignificant for the national, regional, or state economies. Much of it would not exist without irrigation water, and it adds another layer to understanding the basin's socio-hydrology.

Without irrigation, banks, churches, schools, grocery stores, health clinics, implement dealers, and local diners wither and eventually cease to exist. One stakeholder observed that,

> Ultimately the longer you continue to focus the local economy and the local welfare on this fantasy [of endless water] the worse it gets .... you have built this infrastructure out there that is built number one on money that's dependent upon water and [two] it's all mortgaged. And when water isn't there you can't pay the mortgage and the infrastructure begins to collapse. (Manager 2).

On the other hand, the bars usually find a way to survive. Economic innovation outside the agricultural sector can help. Red Cloud, Nebraska (population 948) is undergoing a renaissance of sorts with the rejuvenation of its downtown, the National Willa Cather Center, the restored Opera House, and a child-care center (Hansen 2017), but that is the exception rather than the rule. Furthermore, Grand Island, Nebraska (population 51,000) offers non-agricultural employment and is only an hour away. For these irrigation communities and the growers who live there, a strong and reliable socio-hydrological relationship is critical.

Chapter 8
A Socio-Hydrology Profile and Conclusion

Understanding that the *value* of water has more than one answer is important since the value of water is not necessarily the cost of water. Shown throughout my dissertation are various values of water expressed as ways of knowing from the historical to the hydrological to the personal. My research illustrates how the Republican River, its irrigation districts, and the Compact that ties them together reflect the socio-hydrology of the Great Plains. I have two major outcomes. First, I identify four themes that help to explain the historical socio-hydrology of the irrigation districts and basin's co-evolution with water through time and space with a descriptive profile. Second, I identify 10 thematic categories that socio-hydrology should explicitly include in their discussion and research for values and norms within its organizational framework. These topics are discussed first in the chapter. The dissertation conclusion explores society's enduring and persistent questions about nature by examining whether society has gained a greater understanding of nature and its systems, people's interactions with nature, and how those interactions transcend time and place specifically for the Republican River basin and its environs.

A Socio-Hydrology Profile for the Irrigation Districts

The socio-hydrology of the three irrigation districts and the Republican River basin is a socially constructed space. It is based on physical and social realities, perceptions, and experiences that people have encountered in those spaces. Water must be the foundation upon which everything else is constructed. The four themes ebb and flow throughout the basin, often concurrently. Those themes are droughts and floods, science and technology, litigation, and future adaptations and interpretations. I discuss each in turn.

One: Droughts and Floods

The basin is essentially a place with low stream densities, a semi-arid climate, subject to periodic drought, and with initially inaccessible groundwater. Into this landscape came migrants from the Eastern U.S. whose expectations for economic stability were challenged by harsh physical conditions for agricultural pursuits. Important key events that led to the settlement of the Great Plains were the 1841 Pre-Emption and 1862 Homestead Acts that encouraged settlement and development of federally purchased land. River valleys usually have fertile land and access to streams, so those places were often settled and developed first, as is true in the Republican River basin. If a family farmed, surface water could be diverted by hand dug irrigation canals to water adjacent fields during growing seasons for a harvestable crop. Despite periodic droughts throughout the mid- to late-1800s and early 1900s, many settlers chose to stay on the Great Plains. Then came the 1930s, a prolonged drought that decimated the region and forced innumerable families to abandon their property for the chance of better opportunities elsewhere. In the Republican River basin, hardy settlers eked out a living as best they could under difficult conditions, at least until the 1935 flood. It created a tsunami of destruction made all the worse because of the drought (Manly 1993). Over 100 people lost their lives and economic damages totaled over $13 million Depression era dollars (Manley 1993; Hayden 2015; Figure 8.1). These two events, perhaps more than any other, began to reframe the socio-hydrology of the basin into what residents of the basin know today.

Figure 8.1. 1935 Dust Storm, Naponee, NE (top) and 1935 Flood Cambridge, NE (bottom) (Nebraska State Historical Society n.d.).

Afterwards residents of the basin demanded flood protect from the federal government and wanted irrigation projects to help mitigate water scarcity. The earlier 1902 Newlands Act and the establishment of the Bureau of Reclamation were there to see those needs come to fruition in the establishment of irrigation divisions made possible by the 1944 Flood Control Act and the Pick-Sloan Plan. Throughout settlement, territories and states had developed and enacted water laws and policies that defined how water could be used. Kansas and Colorado codified prior appropriation for all its water. Nebraska took a different path that used prior appropriation with surface water and reasonable use/correlative rights practices for groundwater. Together the development of physical infrastructure for the irrigation districts and the water laws of the states helped to support agricultural economics and create a socially constructed and commodified market-culture value for water. An associated outcome of the flood and water scarcity was the 1943 Republican River Compact. Colorado, Kansas, and Nebraska negotiated an agreement to equitably allocate the virgin water of the river, thereby supplying farmers of the basin with reliable water via Reclamation's irrigation divisions and districts. A 1950s drought and subsequent later ones like the 2012 flash drought are persistent reminders about the unpredictability of the region's climate. Local floods occurred later as well, but none equal the magnitude of 1935. Similar hydro-meteorological events will continue to affect the region into the future.

Two: Science and Technology

Once the infrastructure of the federal irrigation districts was visible on the landscape, the social and water realms became ever more tied to each other. Much of the development during this period can be attributed to scientific and technical advances. Engineering made possible the construction of dams, reservoirs, canals, and diversions that would supply water to basin irrigators. The Compact made sure that the states would have enough water to help power their agricultural economic growth and development of the small communities that followed the river's path. Each state believed that comity was achieved and controversies avoided. My simulated streamflow analysis show that adequate surface water supplies were probable on the South Fork and the main stem prior to the construction of Bonny Dam and Reservoir and Harlan County Dam and Lake. Other tributaries likely saw similar conditions pre- and post-Compact and construction.

Figure 8.2. U.S. Highway 385 between Wray and Holyoke, Colorado (Author).

Initially all was well for surface water users in the alluvial basin and on the adjacent fields. It got better in the mid-1950s when submersible pumps became more readily available and were installed. It got even better for dryland farmers on the basin's upland areas who heretofore had difficulty accessing groundwater for either agriculture or domestic purposes (Figure 8.2). Suddenly wells blossomed everywhere in Colorado, Nebraska, and the upper western basin of Kansas. The Great American desert had become an Eden. The lower Kansas basin was not so fortunate since they are not atop the High Plains Aquifer. Not only were there submersible pumps for the irrigators, the invention of center pivot irrigation technology at the same time meant that fields could be irrigated more efficiently, and what were once considered marginal acres for irrigation were now under the pivot with groundwater. In addition, understanding the hydrological connection between surface and groundwater had been expanded.

Biological genetics has come to play a role as well, especially for seeds. Seed researchers have used genetic engineering to introduce select genes into a plant species or introduce genes from any species into a plant species (Ronald 2011). Crops can then become resistant to insects or viruses and tolerate herbicides and drought (Ronald 2011; Plumer 2012). These benefits can improve agricultural production, soils, biodiversity, nutrition, and reduce negative health effects such as exposure to harsh chemicals (Ronald 2011).

On the Great Plains, drought resistant seed varieties lengthen the amount of time between a plant's need for water because the roots draw water more slowly from the soil (Plumer 2012). Even though universities and private companies invest in drought tolerant seed varieties, no two droughts are alike. Some droughts may occur early or late in a season, some may be driven by less precipitation or extreme heat, and climate change is expected to complicate genetic engineering (Plumer 2012). Benefits to date are modest compared to development timeframes of 10-15 years; plus, the seeds can be expensive (Plumer 2012). Genetically engineered seed must be viewed as a tool that may be most effective in combination with ecological practices, farming practices like no-till, and a move away from mono-cropping, technical changes, and government policy (Ronald 2011; Plumer 2012).

The convergence of submersible pumps, center pivots, hydrological connectivity, and later improved seed genetics amended the basin's socio-hydrology to reflect new relationships between people and water. It also began bringing to the fore tensions between the three states about surface water flows.

The language of the Compact is "virgin waters of the basin undepleted by the activities of man." Kansas interpreted that phrase to mean both surface and groundwater and encouraged the other states, especially Nebraska, to do the same as early as the 1960s, but was rebuffed by the states and the RRCA. Groundwater wells in the upper basin states continued to be drilled and surface flows began to noticeably decline, as demonstrated with the USGS streamflow data. Further, the insertion of dams and reservoirs impacted the river's temporal rhythms and hydrology. The groundwater explosion and disagreement about its role initiates the next theme, litigation (Figure 8.3).

Three: Litigation

For 55 years the states managed to work together, but in 1998 Kansas sued Nebraska in the U.S. Supreme Court for overusing water and breaking the terms of the contract. At the center of the suit was the intent of the Compact framers. Did "virgin waters of the basin" imply both surface and groundwater as Kansas contended or only surface water as Nebraska argued? Controversy had found its way to the basin and to reshape the socio-hydrology. An assigned Special Master oversaw negotiations among the states as they worked towards settling the conflict. The resolution saw the Court assert that groundwater was implicitly included, and a joint development of a hydrological groundwater accounting model. The model is used by the RRCA and the states to quantify each state's annual water use, state water account surpluses and deficits can be identified in a timely manner, and compensatory adjustments enacted. The states agreed to begin using the model in 2006.

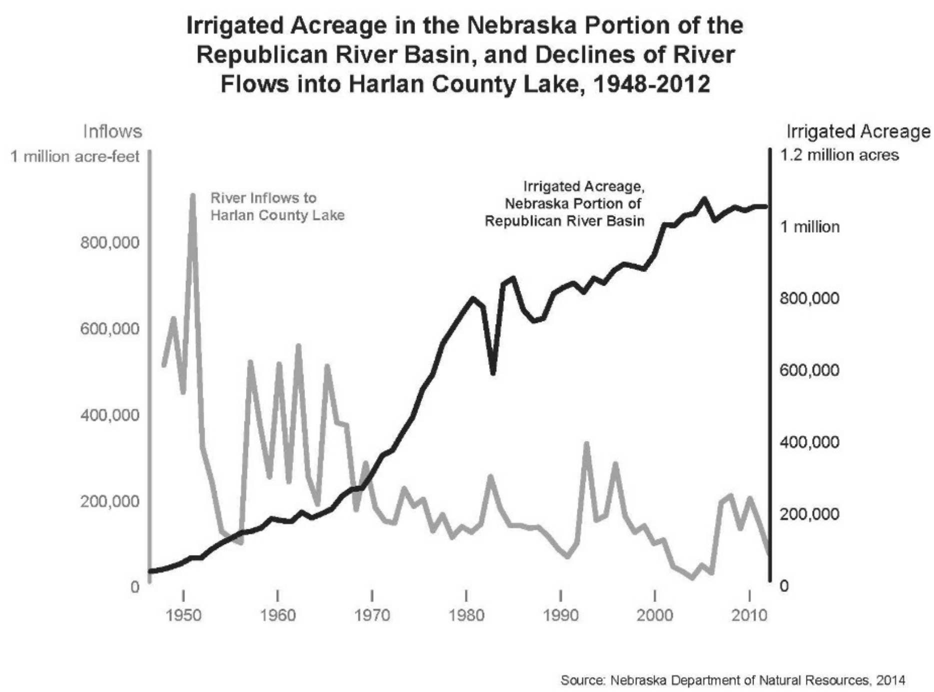


Figure 8.3. Nebraska Irrigated Acres and Harlan County Lake Inflows, 1948-2012 (in Griggs 2017).

Nebraska had been taking steps internally to address groundwater issues with the early formation of Natural Resource Districts (1969) to manage groundwater and later Integrated Management Plans (2005) for joint surface and groundwater planning. The first took place amidst the groundwater revolution, and the second as a way to balance concerns between surface and groundwater irrigators, as well as provide some measure of reassurance to Kansas that Nebraska was serious about delivering water. Surface flows had continued to decline over the decades in the Republican River and both FCID and NBID were increasingly concerned. Those trends are visible in the RRCA base flow and USGS streamflow analyses I undertook; groundwater pumping was having an impact. Despite these and other efforts made by Nebraska, they did not meet their 2005 and 2006 obligation to Kansas. Unable to find common ground, in 2010 Kansas sued Nebraska for a second time. Both Colorado and Nebraska developed groundwater augmentation pipelines as alternative measures to closing water rights, reducing irrigated acres, and being in compliance. These actions were undertaken while the 2010 suit was moving its way through the court system. The pipelines supplement surface water flows to Kansas, and all were operational by 2014. Colorado also voluntarily chose to empty Bonny Reservoir in 2010-2011 on the South Fork of the river to decrease its Compact water deficits. In 2015 the case was resolved. Nebraska disbursed $5.5 million to Kansas, did not have to shut down wells or remove irrigated acres, and was allowed to receive 100% credit for its augmentation water transit; a temporary River Master and pre-determined fines were rejected by the Court. Transit losses due to canal seepage and evapotranspiration are common, reducing the actual volume of water.

Furthermore, FCID and NBID had been increasingly subjected to decreasing irrigation allocations to ensure that the state was Compact compliant. Those actions reflect a number of realities and possibilities. One, water availability for the year was expected to be below average due to physical conditions like drought. Two, groundwater pumping had reduced surface flows to the extent that any flows present needed to go to Kansas. Or three, both conditions existed. The NDNR issues Water Short or Compact Call Year notices restricting access or allocations for FCID and NBID when surface flows are low or inadequate for Kansas' allocation. As a result, both irrigation districts and their members have filed multiple lawsuits against the NRDs and the NDNR over closings and claimed economic damages due to their perceptions of mismanagement by the NRDs, NDNR, and legislative inaction. Interviewed stakeholders are particularly offended by their perceived continued sacrifices and inequities, since they feel that groundwater users have made fewer concessions. Additionally, their legal standing in court is precarious in light of the Compact's language, overriding authority, and Nebraska's legal obligation to it. The Bureau of Reclamation tended to remain on the sidelines even though they have a vested interest in the outcome at the state and federal level.

These intra- and inter-state lawsuits continued to expand and define the basin's socio-hydrology, particularly because established water systems are so entrenched in American politics and institutional histories (Welsh and Endter-Wada 2017a). Value trade-offs that balance efficiency, equity and effectiveness for water allocation practices are often the result (Welsh and Endter-Wada 2017a) which Nebraska has obviously embraced in order to be compliant, but to the detriment of the federal irrigation divisions and projects within the Republican River basin.

Four: Future Adaptations and Interpretation

The socio-hydrology for FCID, NBID, and KBID has revolved around infrastructure that came about due to initial settlement incentives and flood protection. It reflects the Compact language and how it has been interpreted and enacted upon the landscape. Just beginning to touch the districts are global and regional climatic changes as a result of anthropogenic activity (Figure 8.4). In concert with surface and groundwater depletions, those climate changes have the potential to significantly alter the basin's socio-hydrology once again. Should predictions for increasing temperatures and changing water delivery timing hold true, along with a water table that continues to decline, the irrigators, the districts and the states will need to find and develop new adaptation and management strategies that protect their water and economic interests. Protecting the socially constructed market-culture value of water is the defining feature of FCID, NBID, KBID, and the basin's socio-hydrology. What its future iteration becomes will largely depend on unintended consequences and unknown circumstances that will require social decisions that in turn impact hydrological responses.

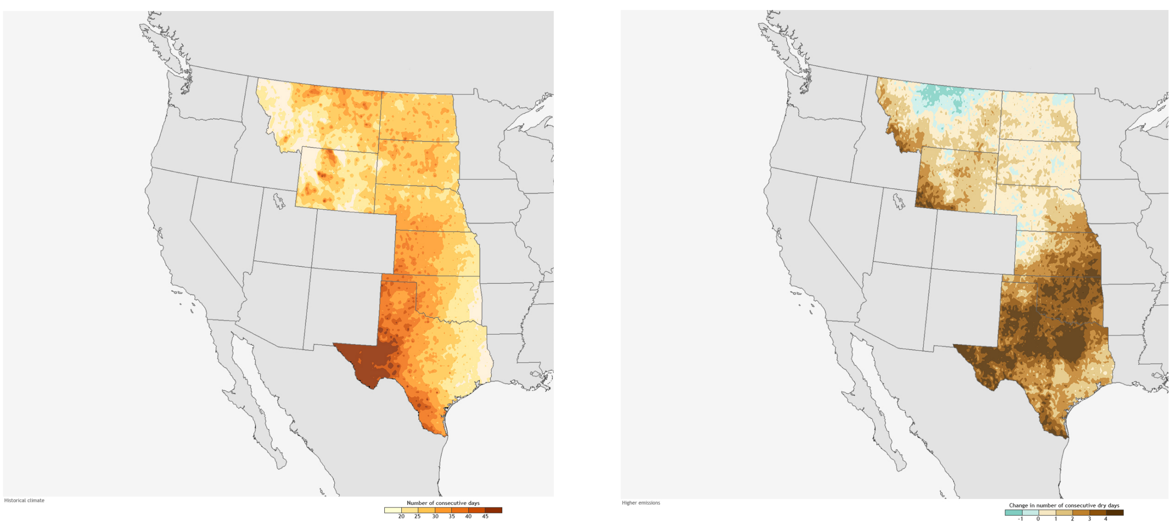


Figure 8.4. Historical and Potential Dry Days for the U.S. Great Plains. Days receiving less than 0.01" of precipitation with the IPCC A1 scenario; historical 1971-2000 (left) and projected 2041-2071 (right) (NCA 2014).

PROPOSED SOCIO-HYDROLOGICAL THEMATIC CATEGORIES

I propose ten thematic categories that future researchers can employ singly or in combination (Table 8.1). While appearing rather commonplace, the literature to date is limited (Sivapalan et al. 2012; Gober and Wheater 2014), and has not discussed at length what categories should be used, how to define them, or how to use them.

Table 8.1. Socio-Hydrology Profile Thematic Categories

Thematic Category	Description
Water	Types and uses of water including quantity and quality–groundwater, surface water, recharge; agricultural, municipal, industrial, and ecological.
Weather and Climate	Local, regional, and global phenomena that impact the hydrology of the area and the people who live there as well as the larger hydrological cycle and climate change.
Ethics, Values, and Perceptions	Inter- and intra-group relationships and interactions that influence water management decisions.
Legal	Federal and state statutes that regulate water; jurisdictional agencies and control; local municipal codes or zoning.
Power and Politics	Legal hierarchies; collective group influence — economic, water managers, coalitions.
Borders	Physical and political borders that mark the spatial extent of water's types and uses, an agency, or a state.
History	Regional and local settlement, economics, cultures and notable events to include the physical landscape.
Technology and Science	Advances in hydrology, engineering, chemistry, geology and other fields that address hydrological connectivity, water access, delivery, and use.
Economics	Macro- and micro-economics that impact water development and use such as industrial uses, cost-benefit ratios, commodities, trade agreements, and globalization.
Demographics	A population's age, gender, education and other relevant characteristics.

(Author)

The Republican River basin's irrigation districts were a mechanism to develop a socio-hydrological methodology that could incorporate social science and human elements not typically used in coupled models and address water management (Sivapalan et al. 2012; Castree 2016, 2017). Socio-hydrology is centered on three ideas or goals: structure and dynamics, outcomes in terms of well-being, and values and norms. It pursues those goals along three research avenues: historical, comparative, and process. My research uses a historical socio-hydrology and values and norms approach with the basin irrigation districts. Future historical and/or values and norms research will need to incorporate thematic categories that can illuminate more clearly a locale's water relationships. The thematic categories also add to socio-hydrology's organization structure (Figure 8.5).

The descriptions in Table 8.1 are representative of how a theme may be defined or used. However, a few observations may be helpful. Local users and decision makers determine what 'fact,' social and/or environmental, counts when choosing how and when to use water. Those choices influence short- and long-term goals. Advances in science and technology can improve quality of life and water efficiencies while also creating unknown and unexpected consequences. Those may lead to dilemmas in areas where water is naturally scarce, but has since become available. Many areas of the Great Plains and Mountain West would have dryland farming if it were not for diverted surface water and groundwater aquifers. Added to those dynamics are the legal boundaries put in place by state and local actors that govern water's jurisdiction and beneficial uses. The borders imposed upon water are mechanisms that groups use to inform and support their way of knowing, and in turn can lead to conflict and power struggles. Power, politics, and their hierarchies direct choices, too, so they must be understood when interrogating the relationship between people on the landscape (Swyngedouw 1997). Schneider and Ingram (1997) specifically discuss the social construction and political power that groups have relative to their position to either receive a benefit or a burden by water management decisions. Further, group benefits and burdens are calculated by the political risk or opportunity they afford to policy makers.

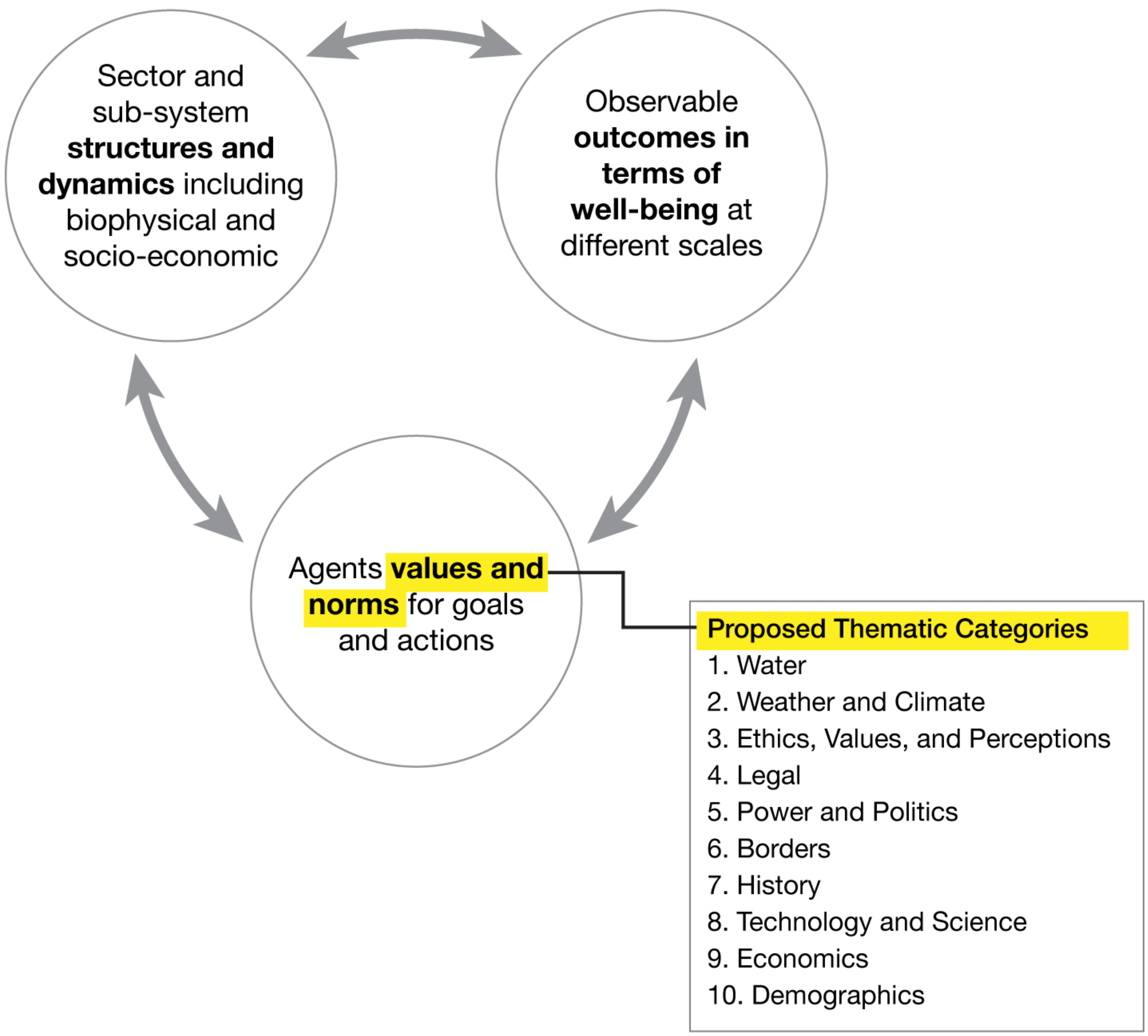


Figure 8.5. Thematic Categories for Values and Norms (Sivapalan et al. 2014, 226) (Author).

Circumstances and situations determine which categories and elements are emphasized. Except for water, no one category is considered more important than another, since together they compose a place's socio-hydrology. The borders between them are porous, particularly in the case of trans-border water conflicts of which the Republican River basin is one example. Socio-hydrology must consider water users and importantly water policies (Feldman and Ingram 2009; Gober and Wheater 2014). Water conflicts in particular are about different ways of knowing and beneficial use (Welsh and Endter-Wada 2017b). To understand those different ways of knowing and their impact requires appropriate research methods for socio-hydrology.

Profile Conclusion

The profile tells a story about a place that has changed through time and space. Today farmers and irrigation districts are using even more technology on the ground and in their combines and tractors in the form of GPS systems; variable rate seed, fertilizer, and water application methods; field weather stations; remote field monitoring through satellites, their cell phones, and the internet; and TCC, total canal control. TCC uses radio signals, computers, and software to control the amount of water in an irrigation canal to reduce water losses. The radio signals connect canal gates and a central server to monitor activity. FCID began using the technology in 2017 on part of its canal system and has been able to reduce losses by 50% compared to losing 4,000 AF a year ago (Brad Edgerton, FCID Manager, pers. comm. 2017).

Farmers and growers have *agri-businesses*, but know that some of their input factors are beyond their control because of the Compact and state regulations. For example, permitting systems have specific conditions and requirements such as water quantity, a legal description of the area, the purpose and so forth. Application fees for agricultural irrigation in Kansas and Nebraska begin at $200, and Colorado charges a non-refundable $100 filing fee (KDA 2016c; CDWR n.d.a.; NDNR n.d.b.).

The empirical knowledge added by my research in the form of a profile and thematic categories expands scholarly research for the Republican River, interstate compacts, and transboundary conflicts.

DISSERTATION CONCLUSION (OR HOW TO AVOID LAWSUITS)

The concerns and practices of those who live in the Republican River basin echo centuries old searches for holistic and simple answers to what is nature, what is human, and how are we connected. The reflexive hydrological responses of decreasing streamflows, losing streams, and groundwater declines are clear consequences in the basin for the social and hydrological decisions people have made. My research and socio-hydrological profile narrative adds qualitative empirical data to the discussion and development of theoretical socio-hydrological models that can if not accurately, at least pragmatically reflect the human-water interface.

The binary construction of human-nature has given way to alternative discourses like hybrids, cyborgs, and Actor-Network theory that ascribe equal value to humans and non-humans alike. Whether binary, hybrid, or other, the human-water cycle is wracked with challenges for quantity, quality, over-use, over-allocation, and scarcity, not to mention trans-border and legal conflicts. Disciplines simultaneously converge and diverge to address these challenges, much like socio-hydrology or hydrosocial research. At their cores they are focused on the relationship between people and water rendering a binary with or without a hyphen obsolete. While cross-currents can revive, and refresh an ontology or epistemology, how we look at the world and what we can know about it, it does not necessarily make answering the complex questions about nature and our relationship any easier.

Challenges

In the Republican River basin, the human imprints on the natural hydrological system are both visible, such as irrigation infrastructure, and invisible, such as a lowered water table. When corn prices are high irrigating marginal acres goes up, and during droughts pumping groundwater takes precedence. Those management choices have contributed to economic advantages and hardships, but at a cost to the river basin's hydrological system, especially surface streamflows. It has led to individual users and decision-makers confronting complex and competing policies for public and private users and natural ecosystems; should water be available for wildlife, irrigators, or cities during periods of scarcity. The Republican River basin and its irrigation districts is an area where many of these conflicts converge in the form of legal disputes, droughts, diminished streamflow, and changing social values about water. It can pit water resource maximizers against generational farmers who want irrigation water for their children and grandchildren to use, as is the case in some instances in the Republican River basin. My research has helped to unravel and shed light on the intricate relationship between water and people, the research itself a hybridity.

From a hydrosocial perspective, Swyngedouw (1997, 1999) posits that an ecological frontier and waterscape can be completely enfolded into the social (urban) setting, where water loses its identity as a unique element or component, instead becoming endogenous within society. I expand the idea of an ecological frontier and apply it to agricultural settings, themselves an urban sphere according to Fitzsimmons (1989), particularly those that depend on irrigation practices. The ecological frontier of the Republican River basin has been wholly consumed by the market-culture values of the irrigators themselves, to the extent that streamflow and water tables are nearly exclusively controlled by management decisions in the form of accumulated surface water in reservoirs, mined groundwater, and yearly irrigation water allocations. There is nothing 'natural' remaining in the basin other than precipitation, because once it is on the ground, it is measured and manipulated to serve social and economic needs.

As surface water becomes less reliable and secure through either human use or climatic change, it is necessary to acquire water from other spaces, primarily groundwater and aquifers. What was once an insurance policy against dry conditions has since become the status quo. Irrigation well drilling and capping technology breaches the hydrological boundary by enfolding the frontier *into* the social rather than pushing the hydrological frontier outward and reducing its spatiality. With groundwater irrigation there is no boundary that technology seemingly cannot surpass. Instead, water frontiers disappear, and boundaries are reached when the resource is depleted and replenishment is impossible, exorbitantly expensive, or too untimely. Although I take a different, more socio-hydrological approach than does Swyngedouw, I still consider relationships produced relative to power, control, and agency important to the discourse.

I focused on historical relationships in examining the Republican River basin's three irrigation districts relative to their hydrological location, the basin's water management decision-making processes, and how water surpluses and deficits impact them. It differs from the majority of socio-hydrology research done to date in that I am not using a hydrological modeling approach. I am incorporating social science methods advocated by Sivapalan et al. (2012), Castree (2016) and others to assist geo-science research and the conversation around global climate changes. I focus on the social interactions — the Compact, water policies, and agencies — that occur in the basin and how they impact the hydrological systems and most obviously declining streamflows. The research extends the hypothetical concept of socio-hydrology beyond modeling into a (or to include a) more comprehensive approach by emphasizing the social element. It is these social elements that are most bothersome in developing workable mathematical models. Troy et al. (2015) state that in some cases their inclusion will be impractical due to data size and their qualitative form. The social variables that I examined (perceptions, language, and history) will be very difficult to integrate. Nonetheless they inform choices that people make about water, and should not be minimized or ignored. A future avenue of pursuit could be the use of agent-based modeling that includes water-use decisions.

Independent systems like climate or technology are significant actors in social and water relations. The Republican River basin has semi-arid climatic conditions that can support rain-fed agriculture, changing surface and groundwater conditions due to irrigation activity, and policy constraints because it crosses political borders. These factors and others have important roles for its future socio-hydrological character. Bengali (2003) and Sivakumar (2011) say that holistic, creative, non-linear thinking and solutions are necessary in both technological and sociological thinking. They stress the importance of development, management, and conservation relative to society, culture, and lifestyle for achieving workable solutions. Along with their states, *all* the Compact basin residents will need to collectively evaluate and choose a watercourse that helps to sustain its overall economic viability using various tools, techniques, and policies.

My research and socio-hydrology profile of the basin offers an opportunity to begin discussions about the present and the future. During interviews and at local Republican River meetings, participants have stated their desire for the basin to look the same. They want agriculture and their communities to take a central position, and water will be a necessity to achieve that goal. Whether or not it is possible within the boundaries of the Compact and current declining water trends may largely be determined by the future. Discussions and decisions made at the local level are usually low risk or maintain the current standards by gently reducing irrigation allocations (Manager 13). Well-designed and applied technology can support and extend the use and life expectancy of water, but if there is no water to use, technology may not be a savior people expect.

Three important variables need special consideration: Reclamation, the Compact and FSS, and federalism. Reclamation has moved away from infrastructure projects towards a water management-oriented mission. They will need to navigate potential revenue losses if the irrigation districts have no water to use and therefore no money to pay for structural maintenance or water storage fees at Reclamation reservoirs. If streamflow declines continue, low reservoir storage volumes will impact water recreation and associated user fees as well. Black swan or wicked problem events cannot be discounted, and foresight can have positive dividends.

Second, the Compact and FSS language will not change. What could change are RRCA rules, future state and federal lawsuits, and state legislative actions that redefine statues, terms and policies. The odds favor both occurrences. Individual state waterscapes will shift in time as a response to water availability, management, and climate change. Third may be a need to modify, suspend, or overcome federalism in the case of trans-basin and trans-border rivers in order to rationally and efficiently manage the joint resource. Watershed management plans (Shrubsole 2004; Roy et al. 2009; Commonwealth of Australia 2017) for interstate river compacts could potentially be another avenue to follow, but it would be a politically risky choice. The success of integrated water resources management has also been questioned (Biswas 2004, 2008). To date, Nebraska and Colorado have not exhibited long-term confidence in their ability to manage their portion of the watershed and maintain downstream Kansas's water allocation. The pipeline solution while a reasonable short-term solution, could itself become obsolete if water table levels precipitously decline and become too expensive to access. Should that happen, the RRCA and the states may have no recourse, but to consider retiring significant irrigated acres in the basin.

Solutions and the Future

Approaches for the basin that incorporate fast and slow processes with unpredictable results due to human activities (Sivapalan et al. 2012), will have to consider changing environmental conditions, competition between surface and groundwater users, transboundary conflicts, policy changes, and economic and global forces. These current and potential future situations originating from independent systems, stakeholders may have to make bold and difficult choices whose results may be uncertain and temporally distant and or imprecise. Ceola et al. (2016) suggest a paradigm shift to low regret solutions based on problem identification, design solutions, and resilience as avenues of pursuit in socio-hydrology. Adaptations are a key component for change. Irrigators have already learned how to maintain productivity with less water, better seeds, soil moisture probes, and field weather stations. Within the basin, a low risk path may be more palatable than other choices stakeholders consider extreme responses, such as permanently reducing irrigation water allocations or un-permitting wells. Chosen solutions will need to fully recognize that not all actors will be appeased, since the basin is a heterogeneous space.

A last approach needs to be considered, the basin's identification as a green society or a technical society. Green societies typically adapt to changing environmental conditions, and technical societies use structural fixes. After the 1935 flood, efforts were undertaken to prevent future loss of life and livelihood with the construction of dams and reservoirs in the basin, a technical response. Other major technical responses include wells, pivots, tractors, GPS and a host of other devices ranging in scale.

Conversely, the Republican River basin is a green society, reflecting adaptability. Through time, especially droughts, they have adapted their agricultural and economic practices to reflect environmental conditions. Until the advent of center pivot irrigation and groundwater access in the 1950s and later, dry land farmers were dependent on timely and adequate precipitation, and irrigation district members were reliant on surface water management by their irrigation districts. With improved agricultural methods including no-till field practices, seed hybrids, timed fertilizers, access to agronomy or university extension services, and other tools, growers were able to adapt to changing environmental conditions on a nearly continuous basis — assess and adjust. It means that their memory is at the forefront, so resilience is high, but technology plays a role in resilience. How long and to what degree a green and/or technological society can flourish without incorporating components from the other depends on a number of factors such as legal challenges, changed environmental conditions, technical developments, and political stability. That merger will by necessity be a hybrid or all encompassing enfolding, a move away from the binary, creating a new iteration of socio-hydrology. People in the Republican basin incorporate both methods to maintain their livelihood. Responding to changing circumstances requires foresight, holistic, interdisciplinary approaches and solutions. Furthermore, courage and political willpower for water management solutions is as transitory as water in places where water is scarce. Other Great Plains socio-hydrologies may demonstrate these same practices and attitudes; further research can explore that possibility. Socio-hydrology is but one means in the search for answers to life's persistent questions about people and water.

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APPENDIX A
TRACTABILITY AND NON-STATUTORY VARIABLE ASSESSMENT FOR THE REPUBLICAN RIVER COMPACT AND FINAL SETTLEMENT STIPULATION

Tractability is all about the ease or difficulty of solving a problem; the more complex the problem the greater its tractability. Technical difficulty is asking how much does it cost and is it available with regard to performance indicators or models that are used on behalf of a statute. Thus dis/agreement about these two questions can help or hinder forward movement.

In its original form, the Compact itself indicates very little in regard to technical implementation or means. The FSS and subsequent model stand in stark contrast due to the Model's high reliance on hydrological modeling and required technological expertise to design the tool itself. In turn, this led to extensive consultations among the States in order to reach an agreement for the design and use of the model, along with its data and how it should be shared. The essential target group are the two irrigation districts and their members, which are a very small percentage of the basin's and each states' populations. The irrigation district members are relatively homogeneous with little diversity in core behavior, so theoretically it should be easy to implement the Compact, FSS and other related documents.

For the first 50 years or so little to no behavior change was expected by the growers in the basin, but with the advent of groundwater pumping, subsequent declining surface flows, and current climate changes, surface water users have had to periodically curtail their district water use and individual allocation. Particularly in Nebraska as an upstream state, this has often meant more adaptations than their Kansas brothers, as they refer to themselves among the districts. In part it can be attributed to differences in Nebraska water law and spatial districting i.e., natural resource districts, along with groundwater users who have had fewer usage restrictions. Therefore, the tractability rating for the Compact, FSS, and Model are low (difficult) rather than high (easy) at the current time. Tractability will ebb and flow due to changes in climatic conditions, state laws, irrigation practices, and other factors, but the end goal is to bring longer-term stabilization to the basin. How achievable it may be under dynamic climatic and legal conditions is uncertain, especially since time is a significant factor for behavioral change, and technological advances are unknown and initially expensive.

The non-statutory variables can be condensed into socio-economic conditions, support, and leadership. Socio-economic conditions are subject to perceptions that wax and wane, local economic variation, a group's economic importance, and technological change. In the Republican River basin, irrigation districts and users are significant contributors to local economies generating millions of dollars, so economic variation as a result of increasing or decreasing irrigation water availability, drought, or farm subsidies for these agricultural producers can cause a ripple effect that in turn influences socio-economic perceptions. Technological changes in irrigation delivery systems e.g., nozzles and droplet size or soil moisture probes, can result in changed economics for the producer and their community. It may be especially true with new technologies that are often expensive and require substantial capital investment, therefore potentially decreasing a producer's discretionary income. In turn, state and national economic variation can further influence public support, attitudes and resources at the local scale. Although not mentioned specifically by Mazmanian and Sabatier, geographic location and place has a role, too.

The Basin States are subject to internal state pressures that can draw needed attention away from the Republican River basin. For example, Kansas is working to solve significant and critical reservoir infilling that threatens municipal water supplies, Colorado is grappling with water demands by growing population centers on the Front Range, and Nebraska's largest metropolitan area, Omaha, faces aging infrastructure along with increased need due to population growth. Thus, statewide perceptions and support may be more transitory than local support and supersede local crises. Leadership can take the form of financial support, oversight and legal actions. What makes the Basin and Compact different is its complex governance.

The Supreme Court is the ultimate authority, but on a day-to-day basis it is the irrigation district. However, districts are subject to local, state, and federal guidelines and policies. These may be contradictory rather than parallel, so leadership falls first on the irrigation districts' governing boards and managers, moving upward to state agencies, legislatures and governors, all of whom have multiple priorities and objectives that can take precedence over the Compact and FSS as long as the statutes are not being challenged. Therefore, it behooves state actors and bureaucrats to show continued commitment, effective support, and consistent enforcement so as to avoid unnecessary leadership challenges i.e., lawsuits that require legislative intervention, taxpayer money and time for solutions.

APPENDIX B

STREAMFLOW ANALYSIS MATERIALS AND ADDITIONAL GRAPHICS

B1. OPEN RECORDS REQUEST

Kansas Department of Agriculture, Division of Water Resources Interstate Rivers and Compacts, Republican River Compact
I would like to obtain: 1. Monthly and annual base flow for the Republican River and its tributaries computed by the Republican River Compact Administration groundwater model for the years of simulation 1918-2015 in the Republican River basin, under both historical conditions (with irrigation) and predevelopment conditions (without irrigation). 2. A list or table of the model gages used to calculate depletions, the accounting points, special definitions, model conditions, and so forth. 3. A model stream network diagram or a link to its online location. 4. An input file to the account program (RRCA) that specifies how each accounting point's impact is calculated as a sum of terms corresponding to model gages. 5. If data could be dispersed in spreadsheet/Excel format, I would appreciate it.

B2. RRCA GROUNDWATER MODEL CONDITIONS

	ALL ON POST DEVELOPMENT OR HISTORICAL	ALL OFF PRE-DEVELOPMENT
Groundwater pumping and return flow	Yes	No
Surface water irrigation pumping	No	No
Surface water irrigation return flow	Yes	Yes
Mound imports (irrigation return flow from Platte)	Yes	No
Irrigation canal seepage	Yes	Yes
Reservoirs	Yes	Yes
Dam Seepage (Bonny)	Yes	Yes

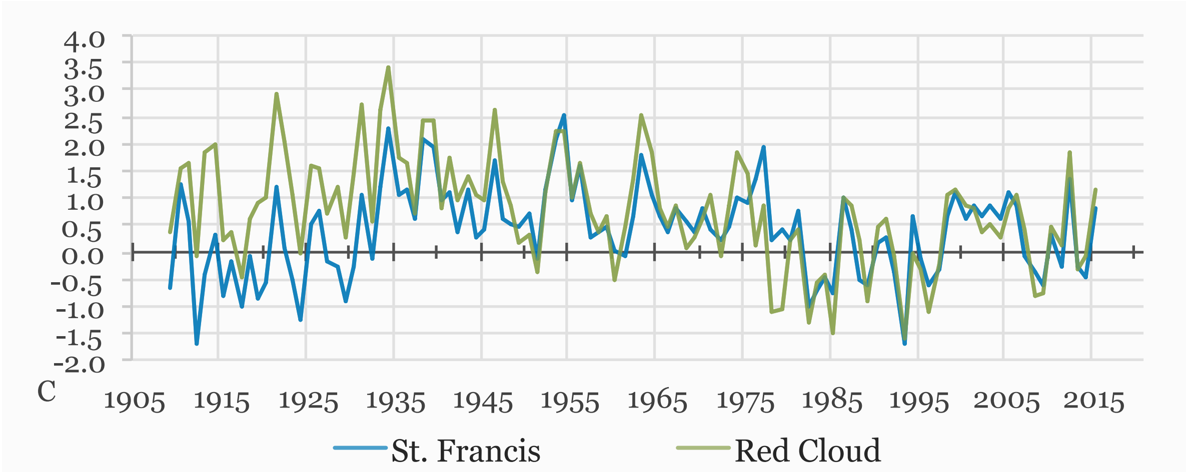


Figure B3.1. St. Francis, KS and Red Cloud, NE Temperature Anomalies, 1909-2015, Climate Normal 1981-2010 (Author).

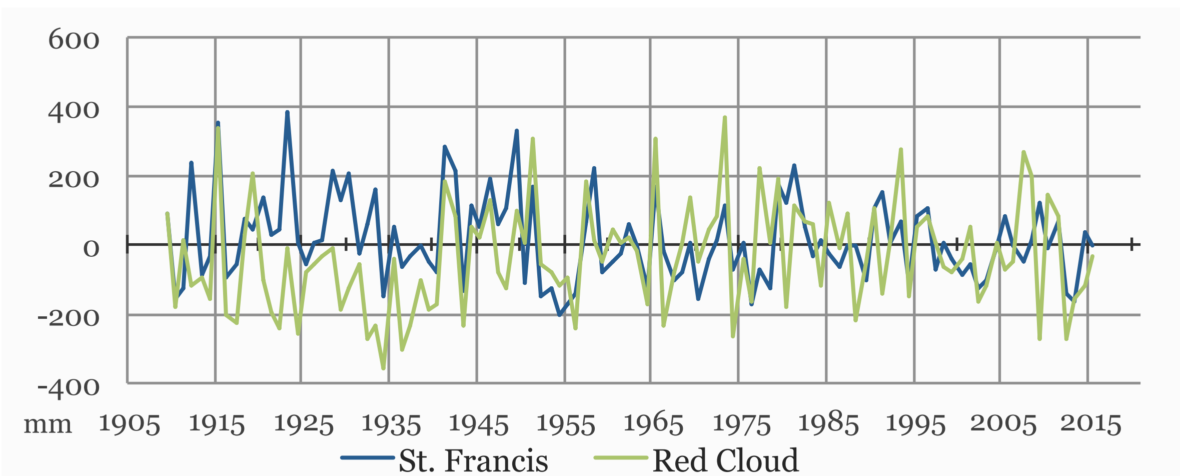
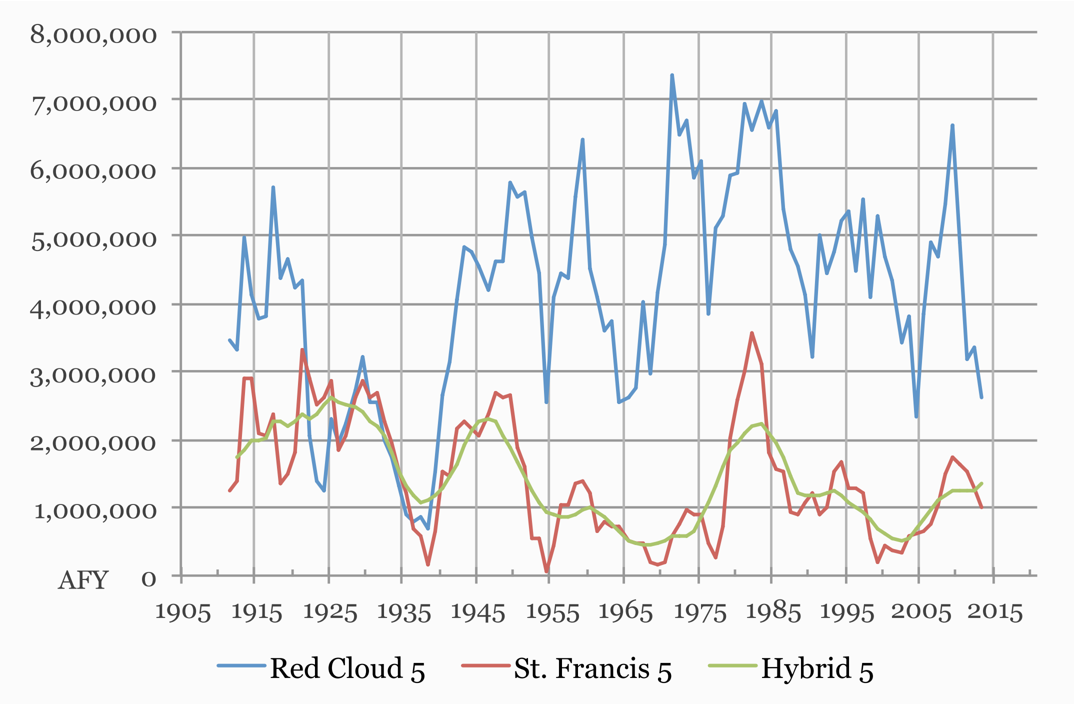
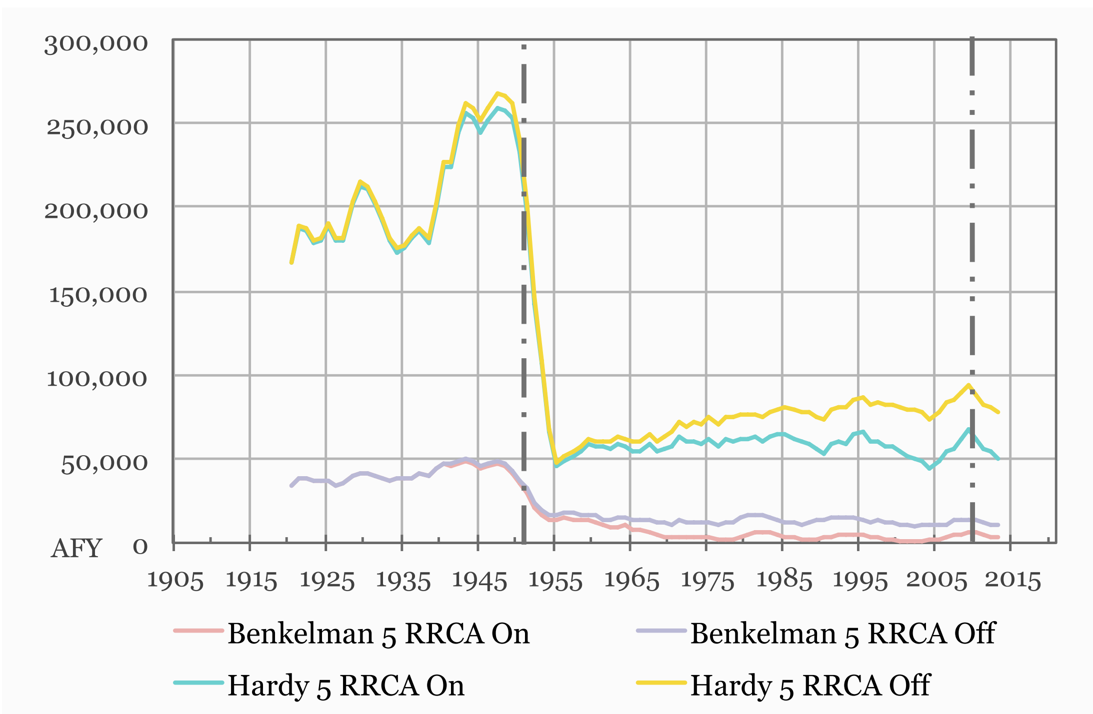


Figure B3.2. St. Francis, NE and Red Cloud, KS Precipitation Anomalies, 1909-2015, Climate Normal 1981-2010 (Author).

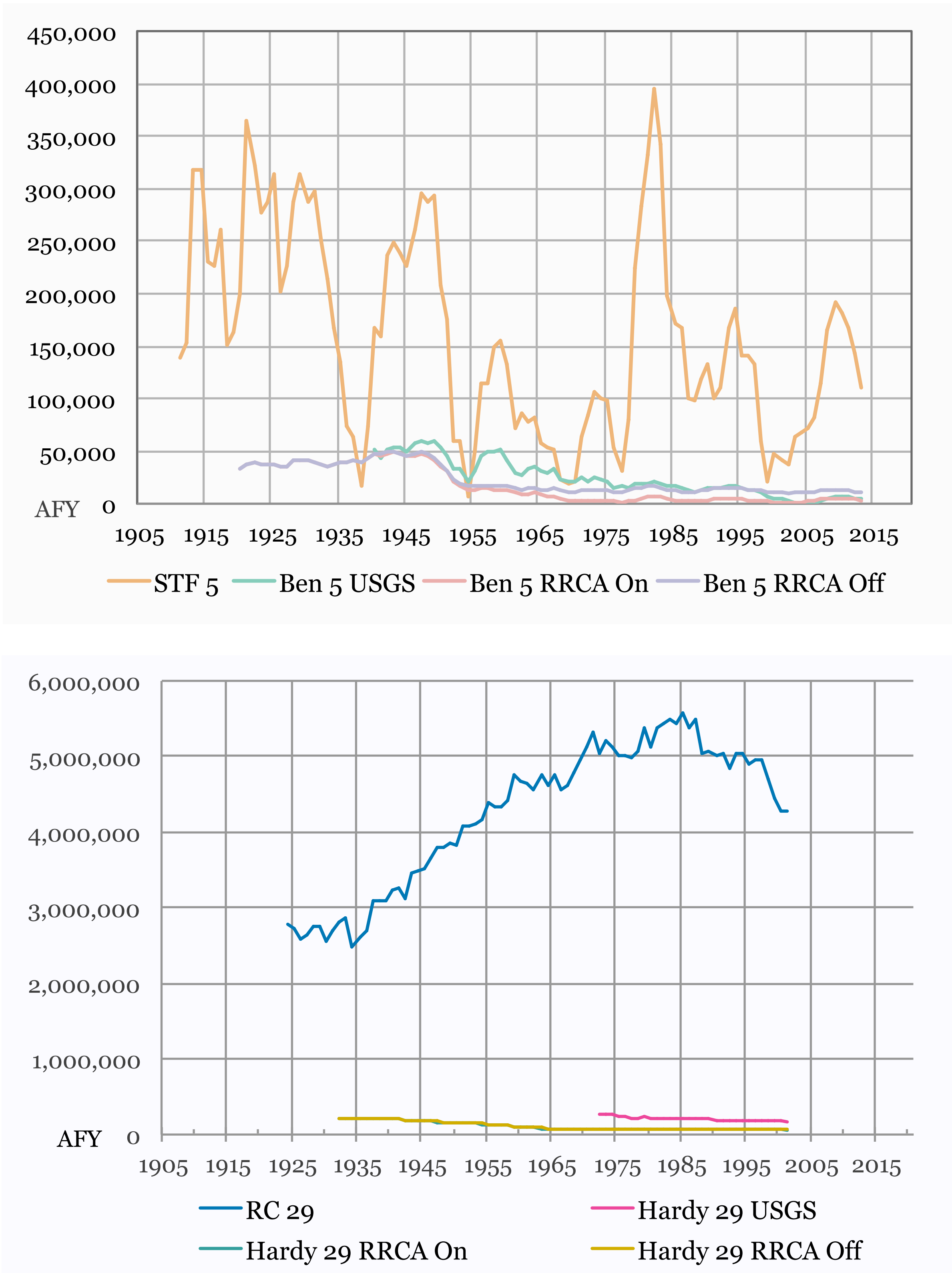
B4. AFY Streamflow Scenario Annual Running Means



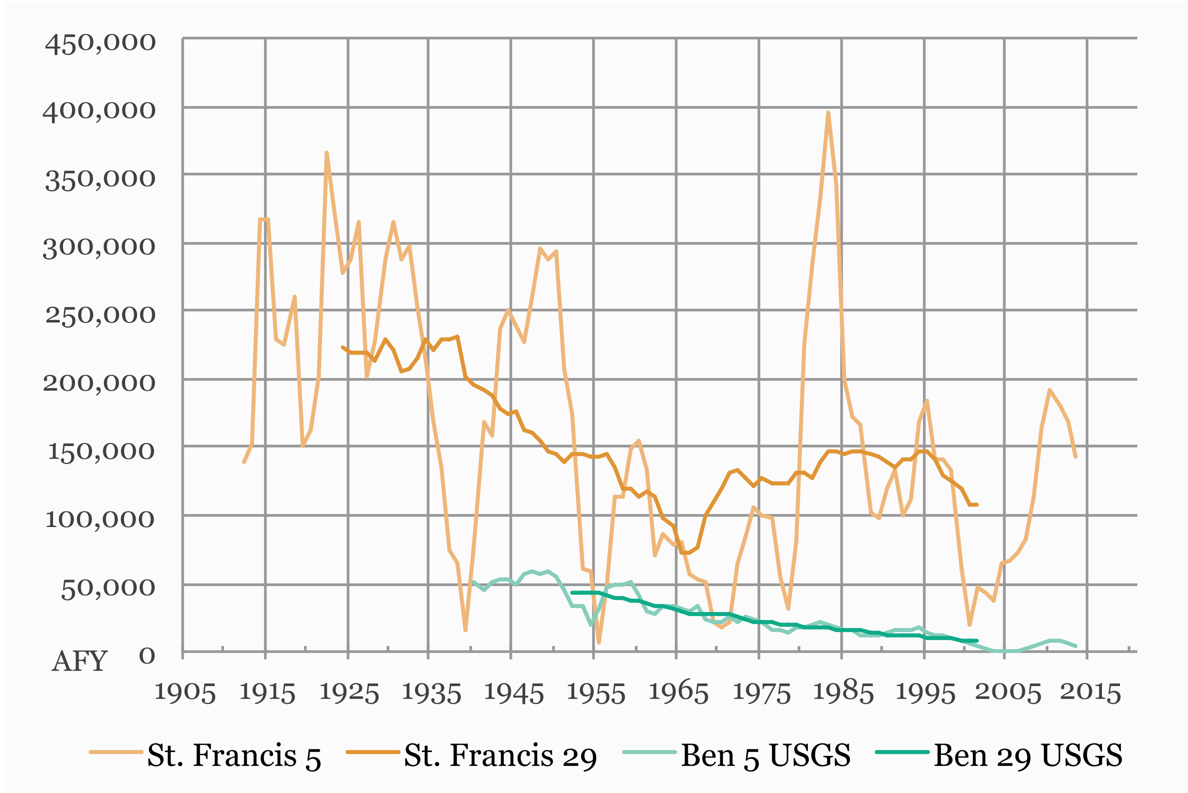
B4.1. AFY Simulated Water Balance Streamflow 5-Year Means, 1910-2015 (Author).

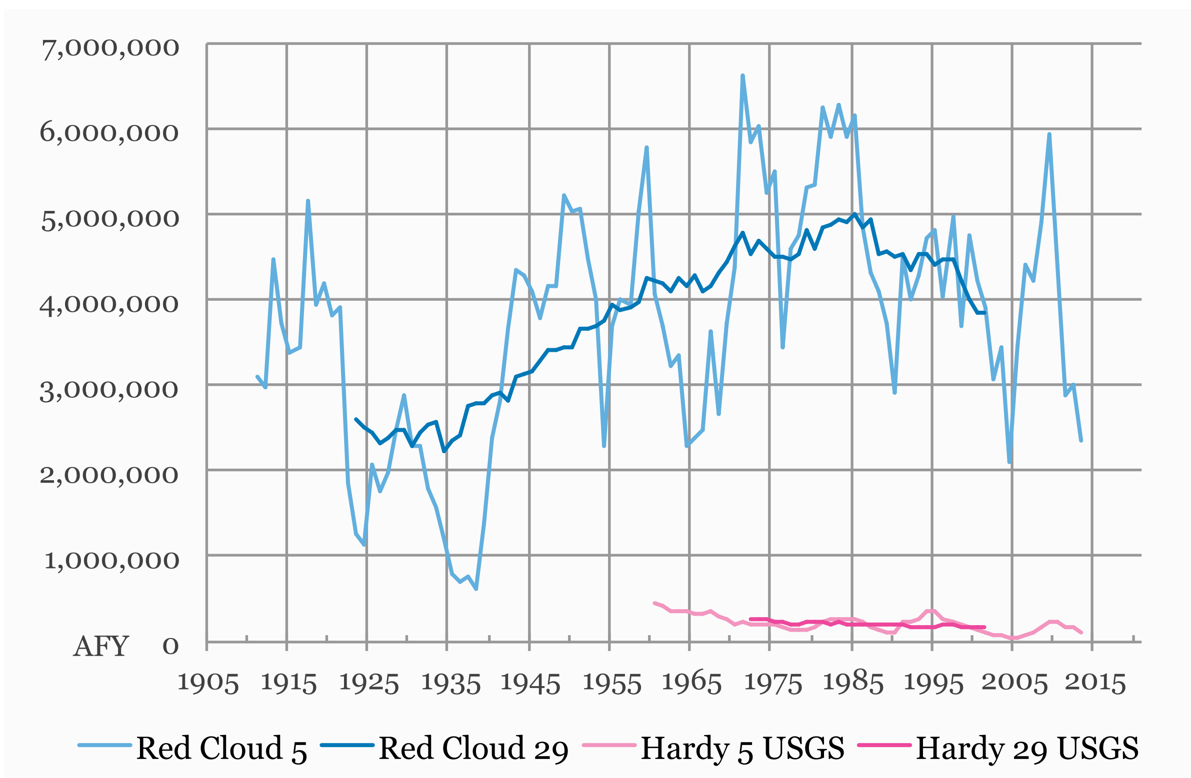


B4.2. AFY RRCA Benkelman and Hardy Streamflow 29-Year Means, 1918-2015 (Author)



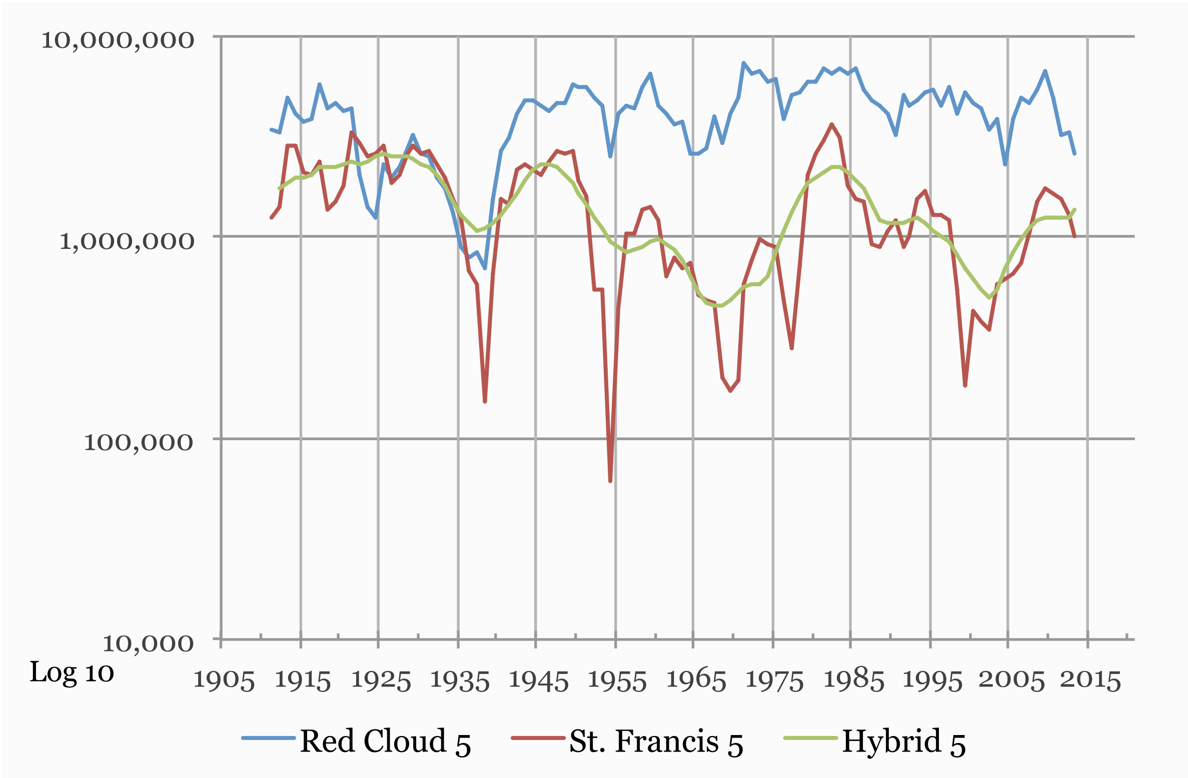
B4.3. AFY Streamflow Scenario Comparison 29-Year Means, 1908-2015. Water Balance, USGS, and RRCA On and Off. St. Francis and Benkelman top, Red Cloud and Hardy bottom (Author).





B4.4. AFY Simulated Streamflow and USGS Streamflow 5- and 29-Year Means, 1910-2015. St. Francis and Benkelman top, Red Cloud and Hardy bottom (Author).

B5. Log 10 Streamflow Scenario Annual running Means



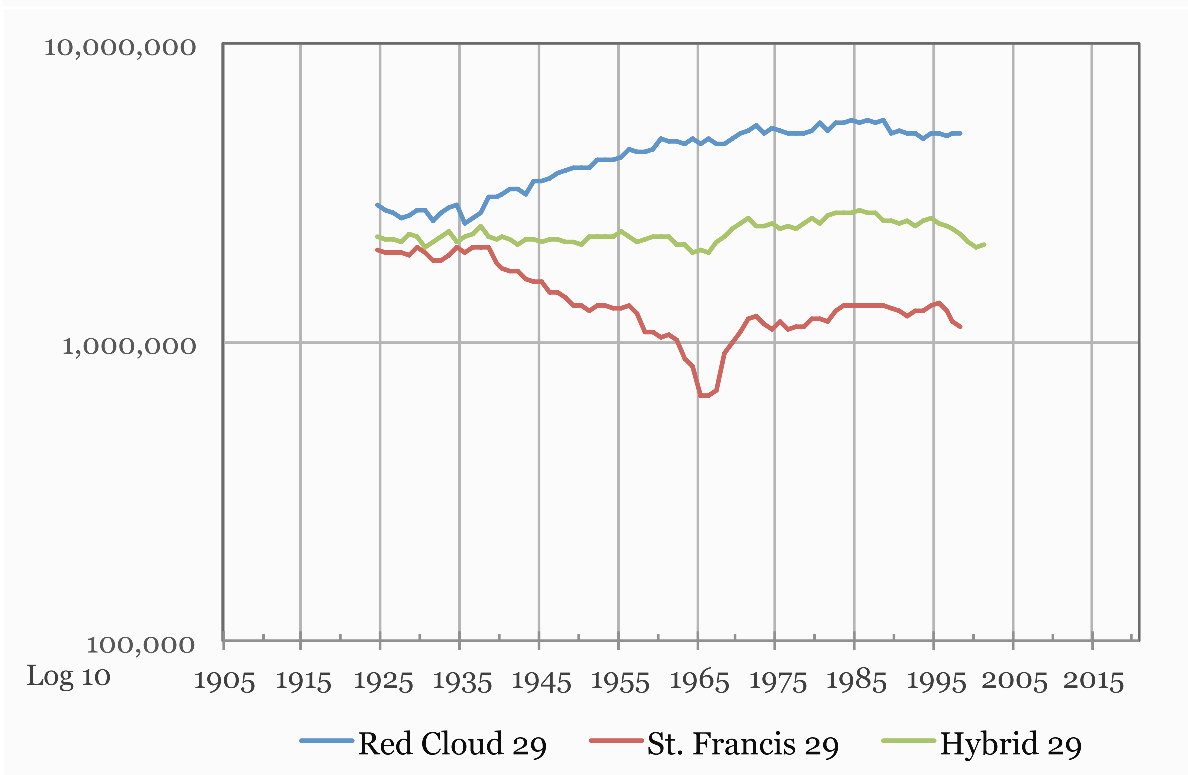


Figure B5.1. Log 10 Simulated Water Balance Streamflow 5- (top) and 29-Year (bottom) Means, 1910-2015 (Author).

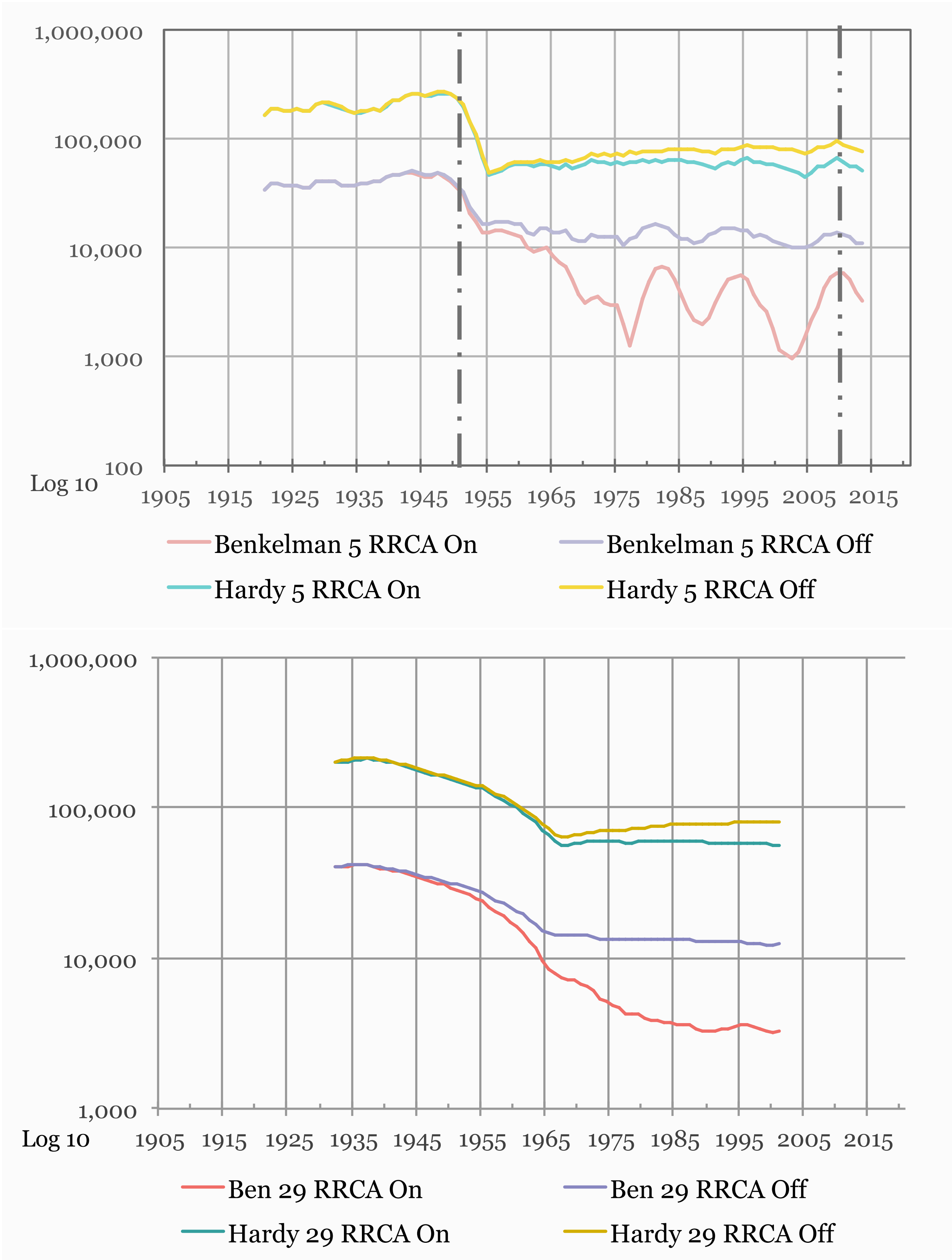


Figure B5.2. Log 10 RRCA Benkelman and Hardy Streamflow 5- (top) and 29-Year (bottom) Means, 1918-2015 (Author). Vertical lines on the 5-year graph represent the completion and emptying of Bonny Dam in 1951 and 2010-11.

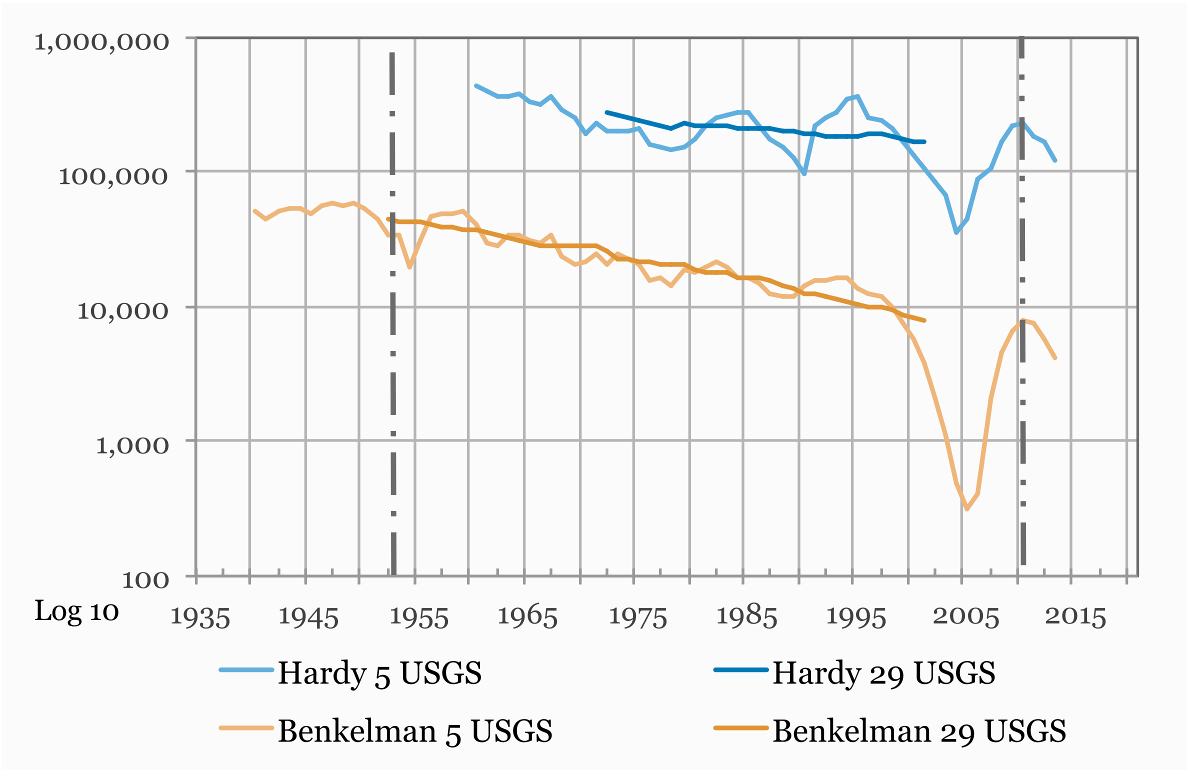


Figure B5.3. Log 10 USGA Hardy and Benkelman 5- and 29-Year Means, 1938-2015 (Author). Vertical lines represent the completion and emptying of Bonny Dam in 1951 and 2010-11.

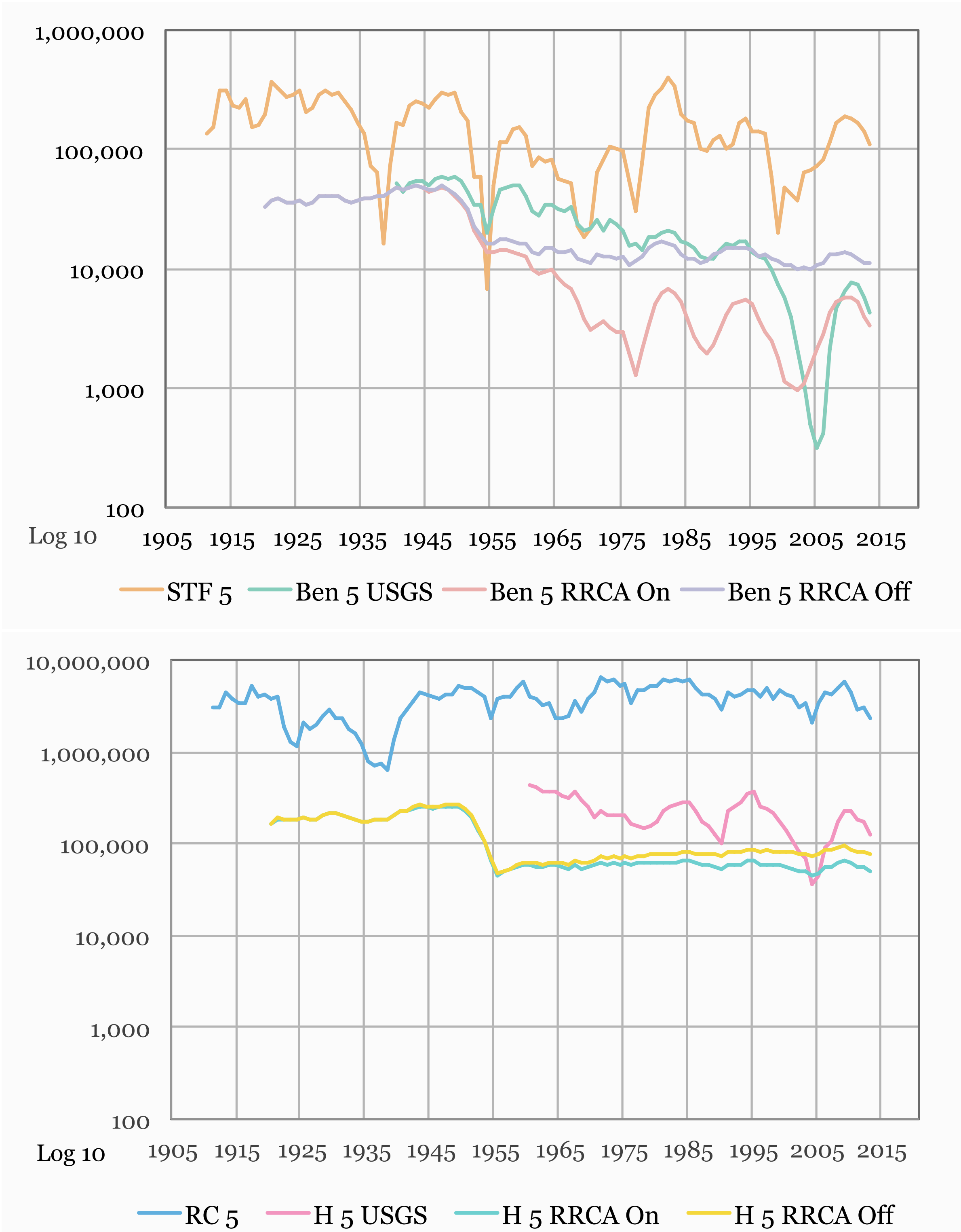


Figure B5.4. Log 10 Streamflow Scenario Comparison 5-Year Means, 1908-2015 (Author). Water Balance, USGS, and RRCA On and Off. St. Francis and Benkelman (Author).

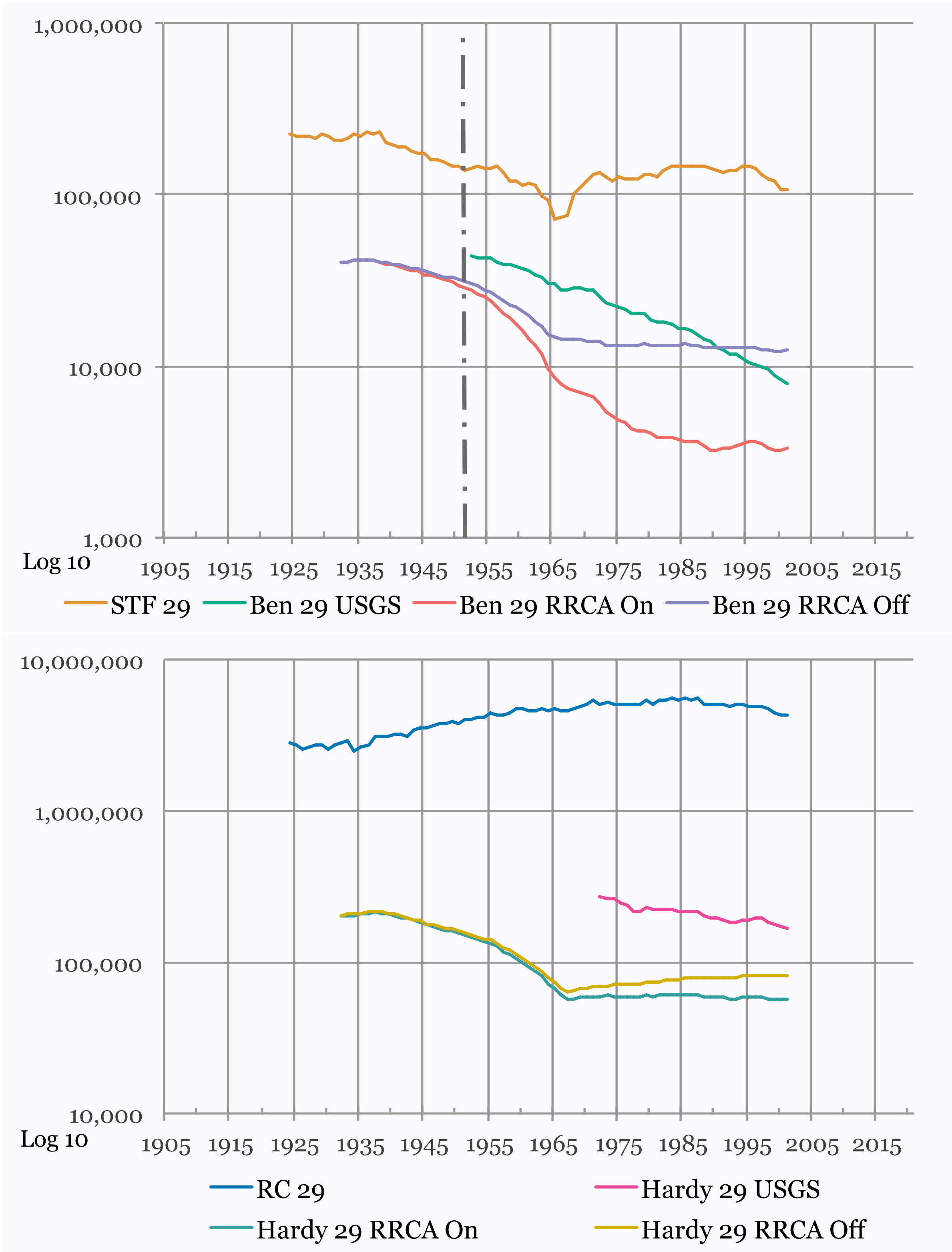
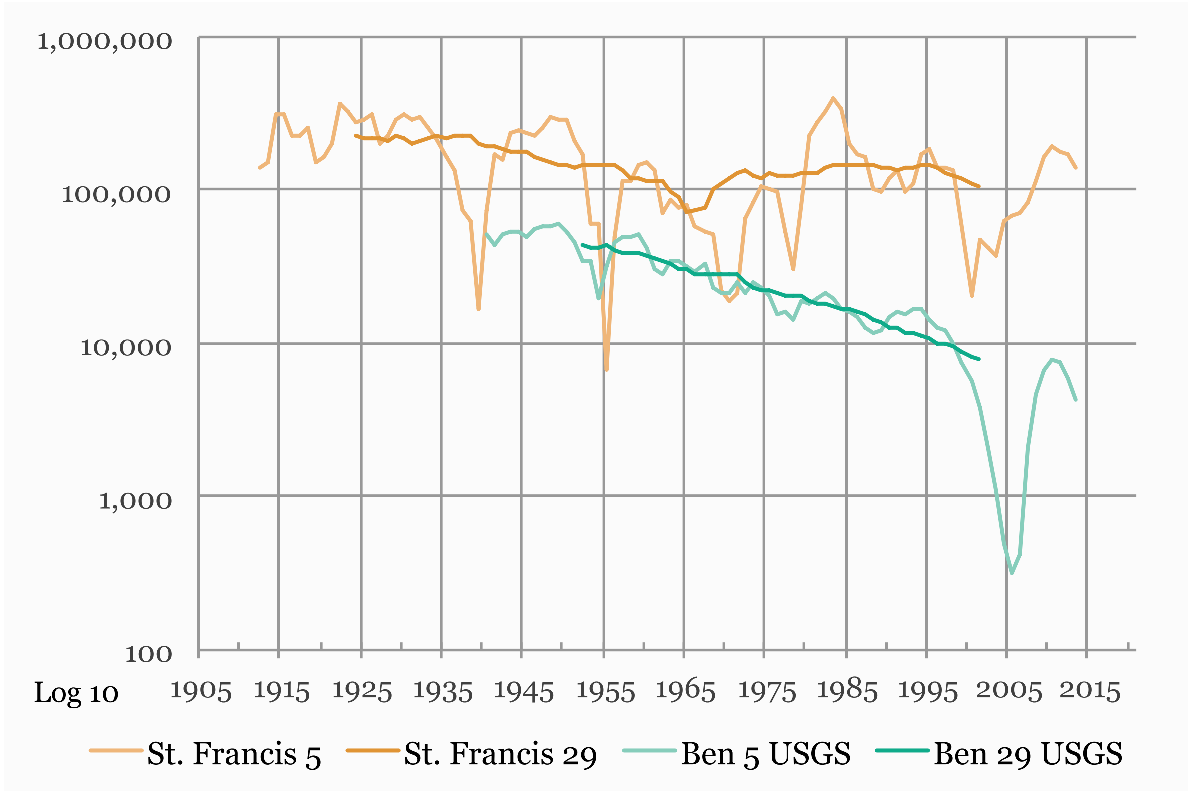


Figure B5.5. Log 10 Streamflow Scenario Comparison 29-Year Means, 1908-2015 (Author). St. Francis and Benkelman, top, Red Cloud and Hardy, bottom. The vertical line for the St. Francis and Benkelman locations shows the completion of Bonny Dam in 1951.



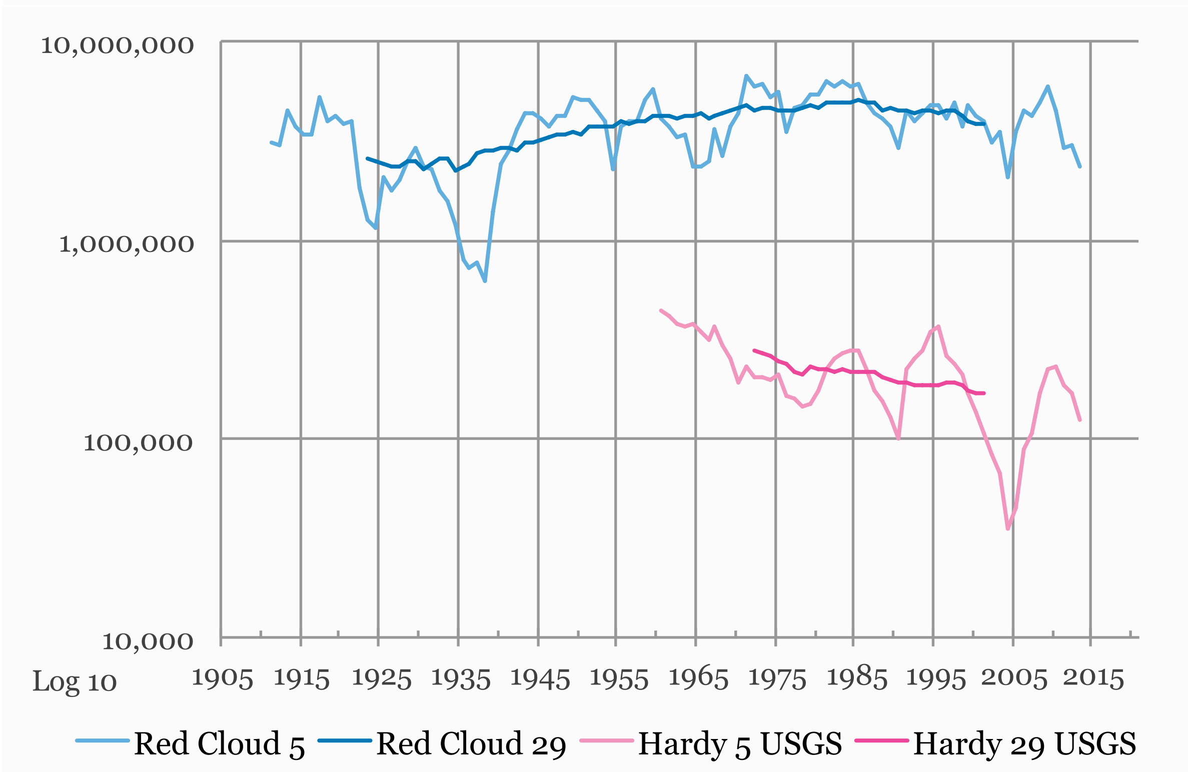
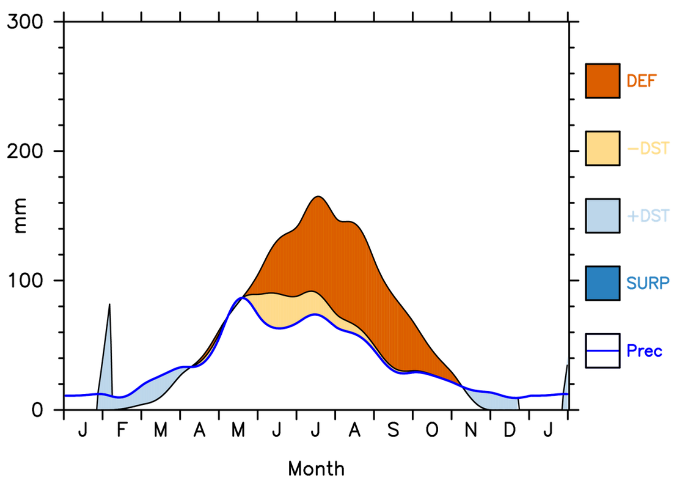


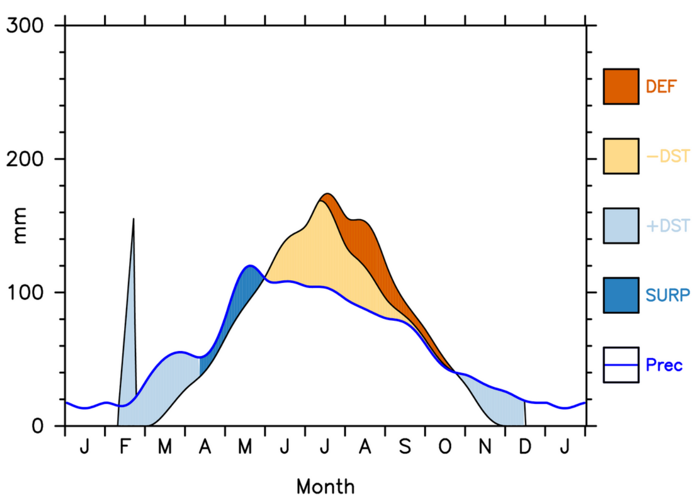
Figure B5.6. Log 10 Simulated Streamflow and USGS Streamflow 5- (top) and 29-Year (bottom) Means, 1910-2015. St. Francis and Benkelman top, Red Cloud and Hardy bottom (Author).

Water Balance at 102W, 40N
Project Title: St. Francis, KS



Location: **102W 40N** Elevation: **1032 m**
Soil water-holding capacity: **150 mm**
Declining availability function: **G**
Prescribed average-monthly air-temperature changes: **0.0ºC**
Prescribed average-monthly precipitation changes: **0.0 %**

Water Balance at 98W, 40N
Project Title: Red Cloud



Location: **98W 40N** Elevation: **468 m**
Soil water-holding capacity: **150 mm**
Declining availability function: **G**
Prescribed average-monthly air-temperature changes: **0.0ºC**
Prescribed average-monthly precipitation changes: **0.0 %**

Figure B6.1. Water Balance Soil Moisture for COOP Stations St. Francis, KS (top) and Red Cloud, NE (bottom) (WebWIMP n.d.). Water holding capacity 150mm.

B7. RRCA Republican River Basin Stream Diagram

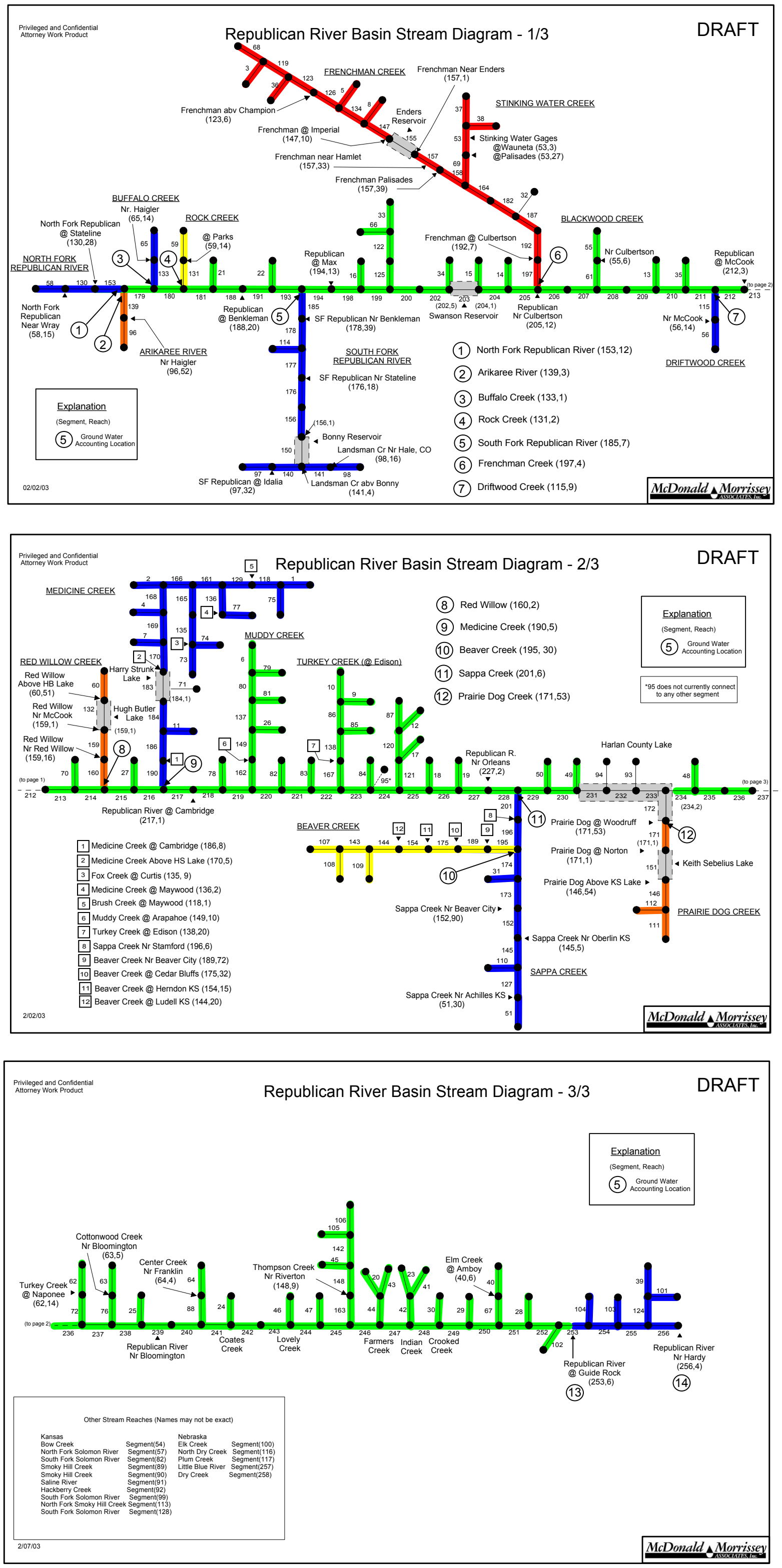


Figure B7.1. RRCA Republican River Basin Stream Diagram (RRCA n.d.c.).

B8. RRCA Groundwater Model Soil Types

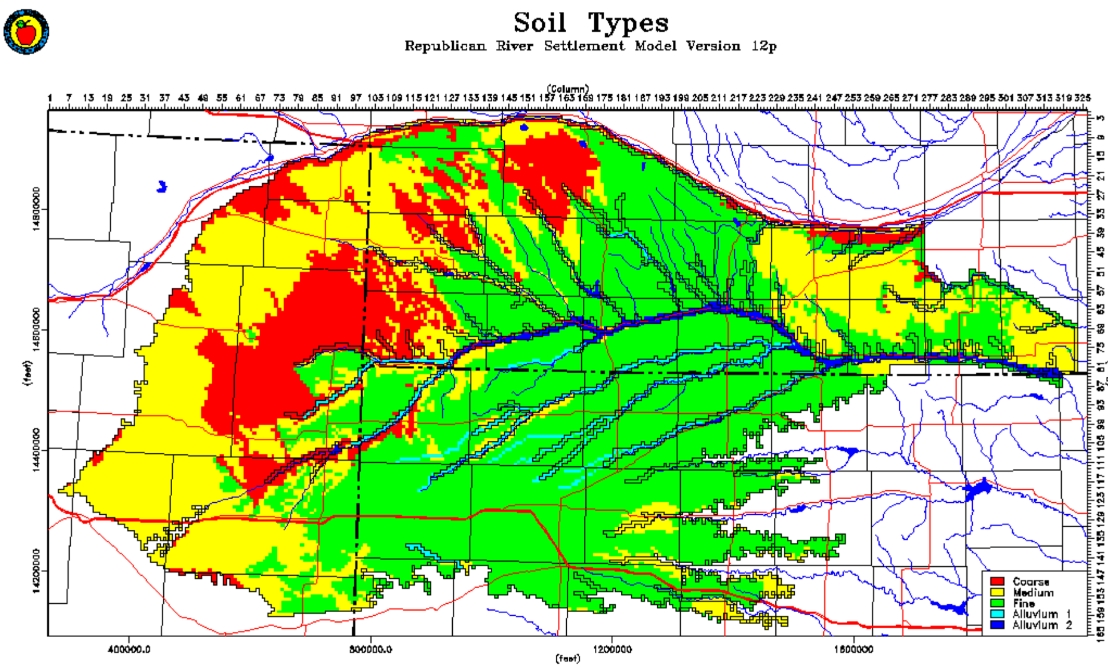


Figure B8.1. RRCA Groundwater Model Soil Types. The geographic boundaries exceed those of the drainage basin due to hydrological conditions (RRCA n.d.c.).

APPENDIX C
INTERVIEW MATERIALS

C1. NOT HUMAN RESEARCH IRB APPROVAL

THE UNIVERSITY OF KANSAS
Research

NOT HUMAN RESEARCH

November 19, 2015

Jean Eichhorst
jean.eichhorst@ku.edu

Dear Jean Eichhorst:

On 11/19/2015, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Water resource managers' perceptions in the Republican River basin
Investigator:	Jean Eichhorst
IRB ID:	STUDY00003410
Funding:	None
Grant ID:	None
Documents Reviewed:	• Eichhorst oral consent, • eichhorst_eCompliance.pdf, • eichhorst phone contact, • eichhorst email contact

The IRB determined that the proposed activity is not research involving human subjects. IRB review and approval is not required.

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are being considered and there are questions about whether IRB review is needed, please submit a study modification to the IRB for a determination. You can create a modification by clicking **Create Modification / CR** within the study.

Sincerely,

Stephanie Dyson Elms, MPA
IRB Administrator, KU Lawrence Campus

Human Subjects Committee Lawrence
Youngberg Hall | 2385 Irving Hill Road | Lawrence, KS 66045-7568 | (785) 864-7429 | www.research.ku.edu

C2. Interview Contact Materials

Phone Contact For Interview Participation

Hello, my name is Jean Eichhorst and I am a University of Kansas Geography doctoral graduate student conducting research in the Republican River basin exploring water resource managers' decision-making based on environmental conditions and the need to maintain compliance with the Republican River Compact.

I am interested in conducting an interview with you about your experiences and views about water management in the basin. An interview would take about an hour, be 6 questions long, and be confidential and anonymous. Would you be willing to meet with me? If you can't is there someone you could refer me to as an alternate?

I appreciate your help.

You can contact me at (phone number) or email me at (email address).

Thank you,
Jean Eichhorst

Email Contact For Interview Participation

Hello, my name is Jean Eichhorst and I am a University of Kansas Geography doctoral graduate student conducting research in the Republican River basin exploring water resource managers' decision-making based on environmental conditions and the need to maintain compliance with the Republican River Compact.

I am contacting you because you are directly involved with water management in the basin, and I am interested in conducting an interview with you about your experiences and views. Interviews would last about an hour and consist of 6 questions. Your responses would be recorded (and later destroyed), will be confidential and anonymous, and you're under no obligation to participate. Preferably I would like to conduct a face-to-face interview, but if this isn't possible, we can make other arrangements.

Since your time is valuable, I appreciate your consideration of my request. Please let me know about your willingness to participate, and we can make arrangements to meet. If you are unable to do the interview, but know someone else who would be helpful, please pass my contact information along to them. You can also contact my advisor, Barney Warf (email) or the KU Human Subjects Protection Office (785.864.7429, irb@ku.edu) for additional information.

Thank you,
Jean Eichhorst
PhD Candidate, Geography
University of Kansas, Lawrence, KS
email
phone

C3. Oral Consent Statement

Before we start the interview, I need to read an oral consent statement to you, so that you understand the purpose of the interview and your rights as a participant. A verbal response at the end of the statement will signify your participation status.

I am a doctoral candidate at the University of Kansas's Geography Department conducting research in the Republican River basin exploring water resource managers' decision-making based on environmental conditions and the need to maintain compliance with the Republican River Compact.

I will be asking you about short- and long-term challenges in the basin for water managers, water users, the Compact, and related water issues. Anonymity and confidentiality will be maintained. You have no obligation to participate and you may discontinue your involvement at any time today or after the interview. Participation in the interview indicates your willingness to take part in this study and that you are at least 18 years of age.

The interview will last approximately an hour and consist of 6 questions, with the possibility of a few follow up questions. With your consent, I would like to record it for research purposes. Recording is not required to participate. You may stop the recording at any time. The recordings will be transcribed and translated. Recording access will be limited to me and my faculty supervisor. They will be password protected and destroyed/deleted following transcription and analysis. Do you have any questions?

If you have later questions, I can provide you with contact information for me, my advisor or KU's Human Subjects Protection Office.

Do you understand the purpose of the interview and are you willing to continue? Thank you.

C4. Interview Questions

These questions were adapted throughout the interviews depending on the individual and group.

1. Could you tell me about the short- and long-term water management challenges you have in your district for your users, and the impact those may have on receiving water plus meeting the Republican River Compact requirements?

2. Augmentation plans in Colorado and Nebraska have been implemented to ensure that water is available and deliverable to downstream users. How do you perceive their short- and long-term augmentation viability for your district and the Compact?

3. What steps has your district considered in response to predicated temperature increases and precipitation decreases, e.g., higher temperature minimums and less water during the growing season for the region and basin? What kind of response have they received?

4. What kind of collaboration has your district participated in to manage water in the basin? Has it been beneficial to your district and its ability to meet Republican River Compact requirements?

5. Have conjunctive use and correlative rights changed water management in the basin generally and in your district specifically? If so, in what way?

6. What else would you like me to know about your district, the basin or the Compact regarding water or its management?